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The Mine Explosion at Johnstown.

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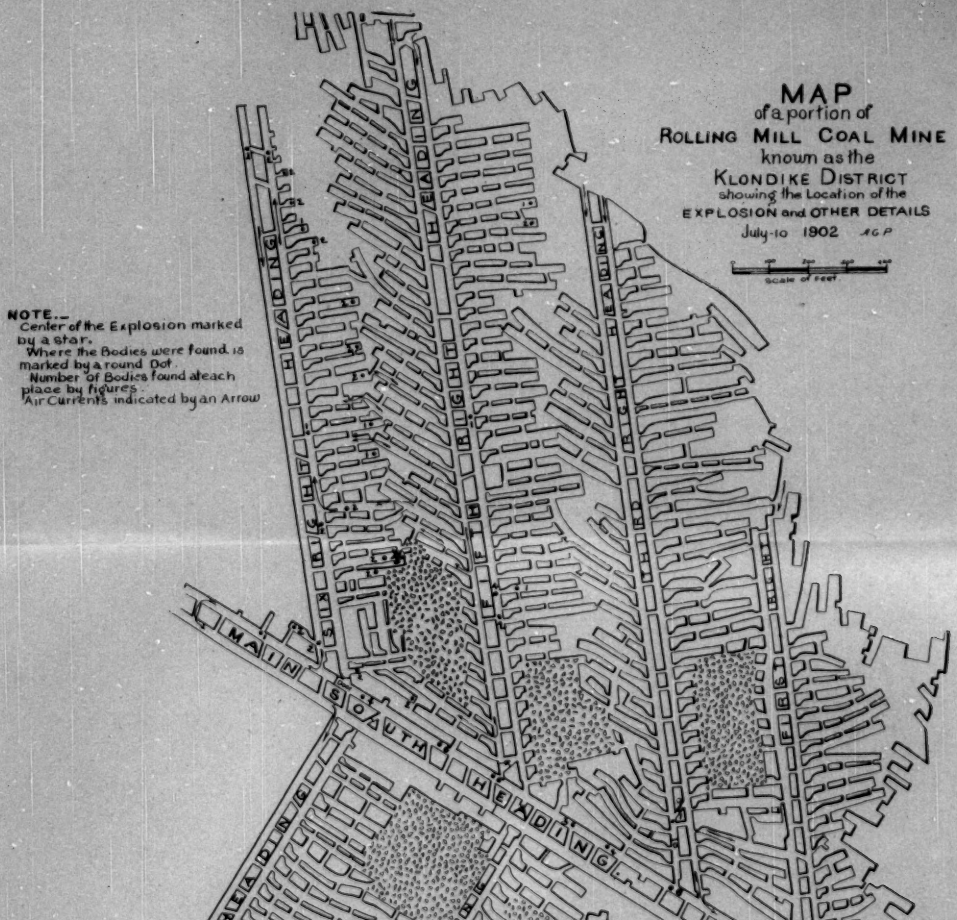
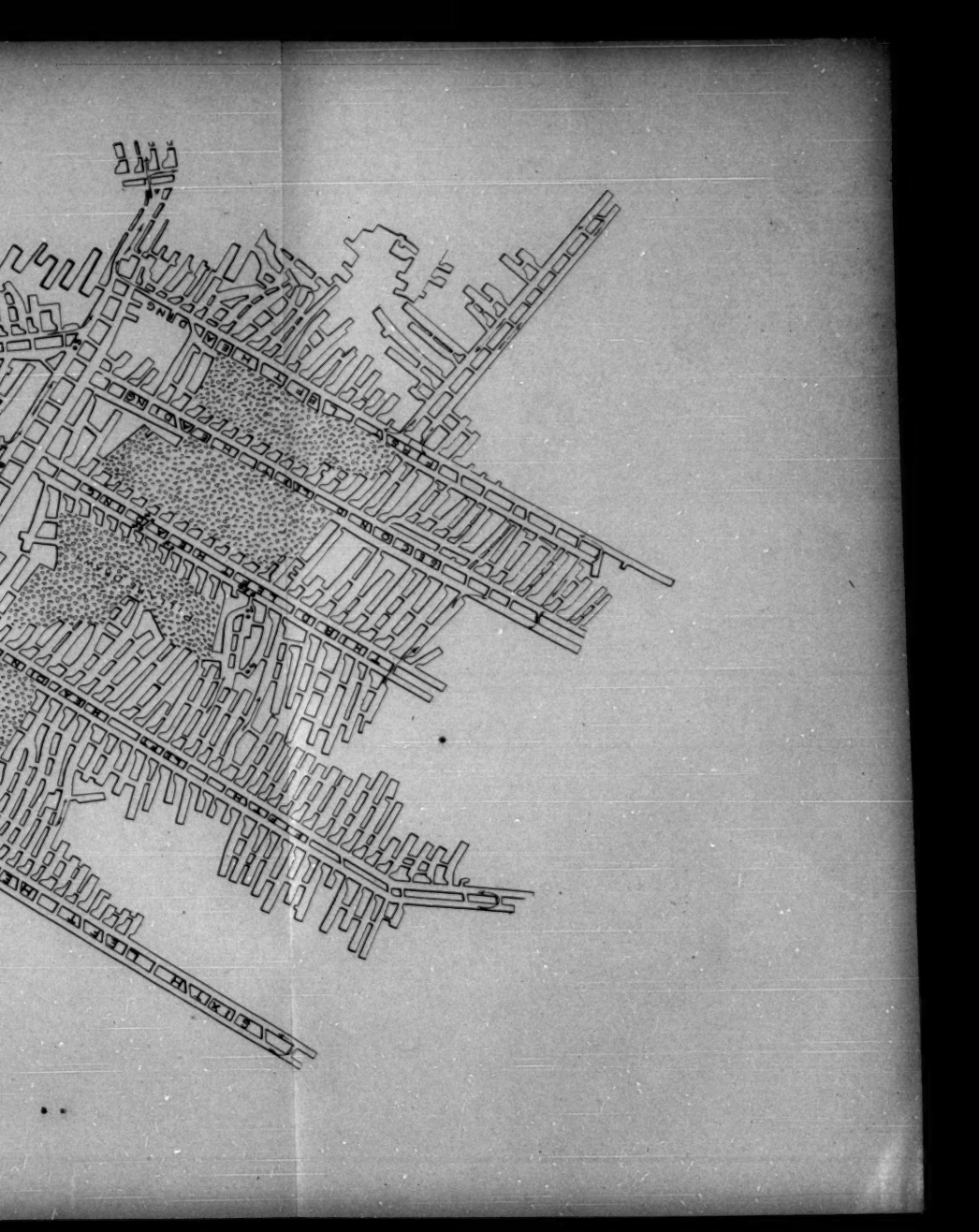
On the tenth day of July, 1902, there was an explosion of fire damp in the Rolling Mill mine of the Cambria Steel Company at Johnstown, Pa., which resulted in the loss of 112 human lives, and was, in this respect, probably the most disastrous that ever occurred in the State of Pennsylvania.

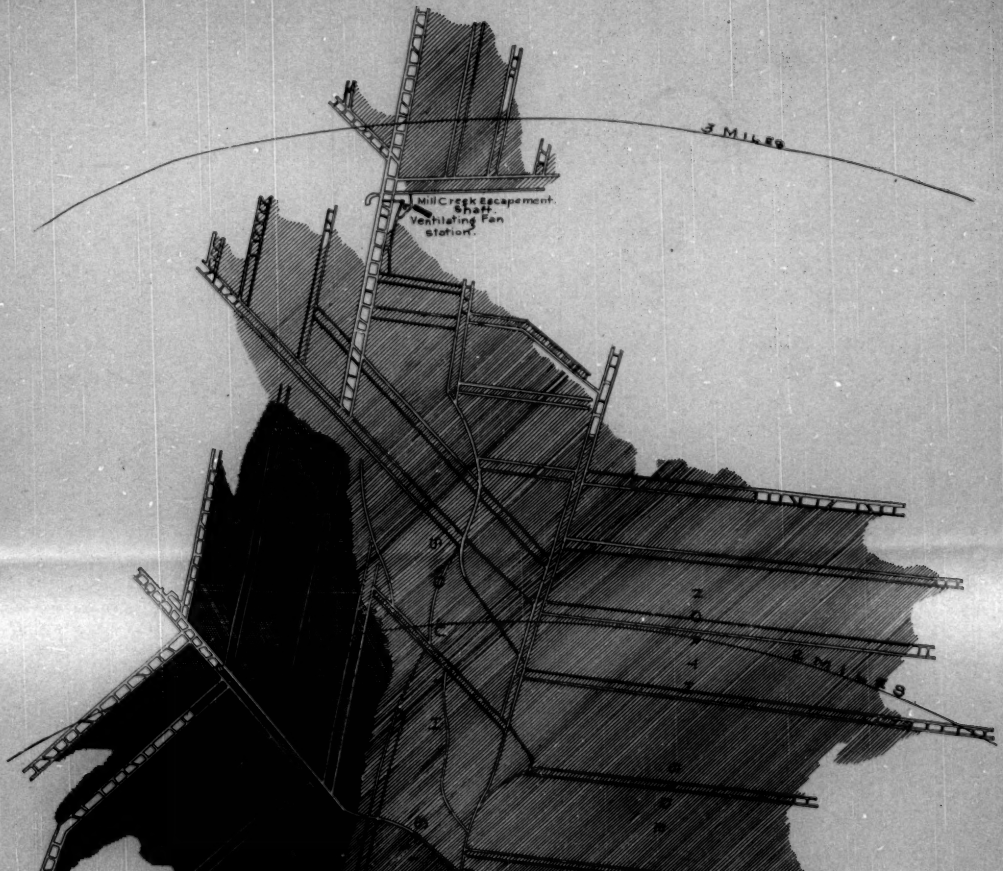
The explosion presents some such peculiar features that a statement of the facts relating to it may possibly be of interest to the members of the Institute.

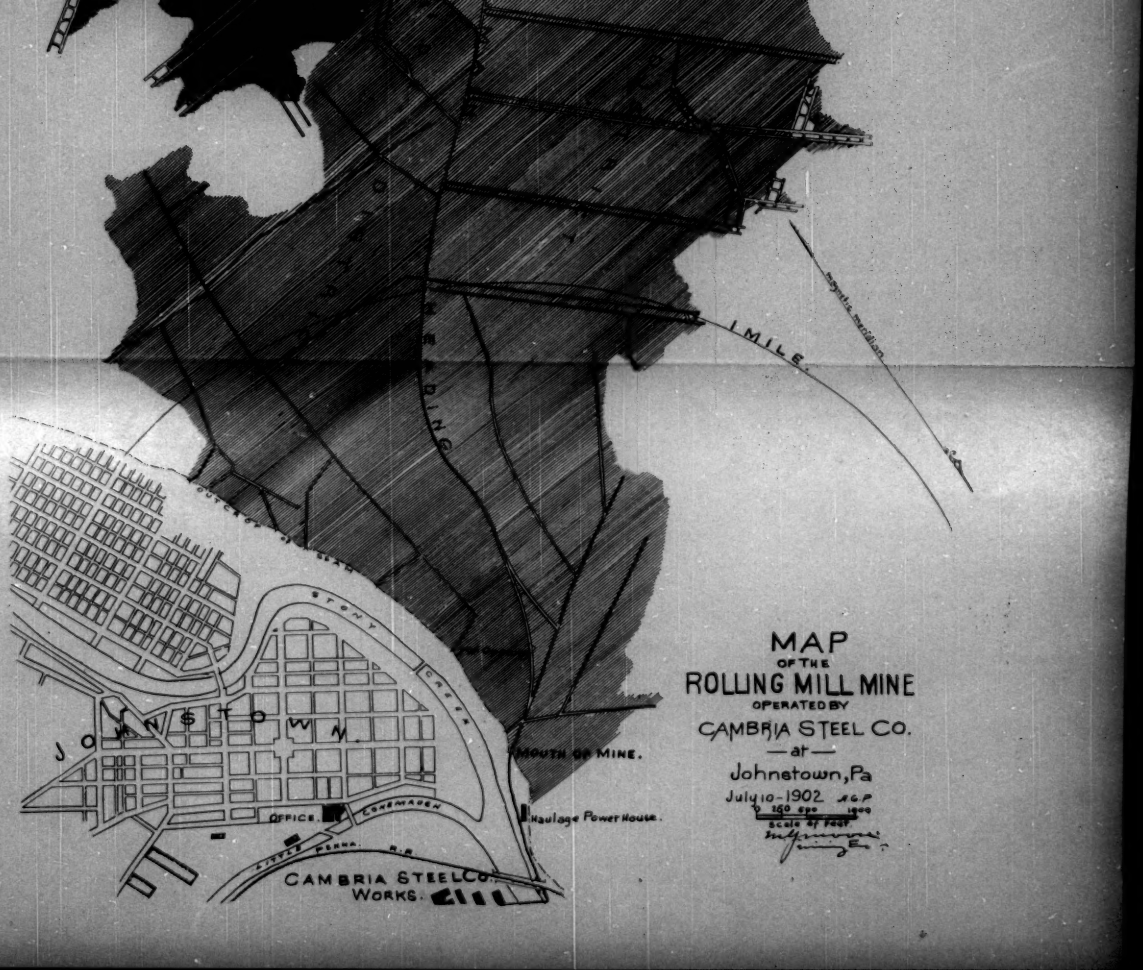
DESCRIPTION OF ROLLING MILL MINE.

The Rolling Mill mine was opened by the Cambria Iron Company in 1856 to supply their mills and works with coal and, with the exception of the two years of 1888 and 1889,


MAP
of a portion of
ROLLING MILL COAL MINE
known as the
KLONDIKE DISTRICT
showing the Location of the
EXPLOSION and OTHER DETAILS
July 10 1902 AGP
Scale of Feet
NOTE.-
Center of the Explosion marked by a star.
Where the Bodies were found is marked by a round Dot.
Number of Bodies found at each place by figures.
Air Currents indicated by an Arrow
MAIN SOUTH HEADING
BIG SEVEN HEADING
BIG EIGHT HEADING
BIG NINE HEADING
BIG TEN HEADING




3 MILES
Mill Creek Escapement Shaft.
Ventilating Fan station.
UNION DIP
2 MILES


1 MILE.
Magnetic meridian.
STONY CREEK
JOHNSTOWN.
MOUTH OF MINE.
OFFICE.
LONEMAHON
Haulage Power House.
CAMBRIA STEEL CO. WORKS.
MAP
OF THE
ROLLING MILL MINE
OPERATED BY
CAMBRIA STEEL CO.
—at—
Johnstown, Pa
July 10 - 1902
Scale of Feet

when natural gas was abundant in Johnstown, has been in continuous operation. At first the tonnage was small, and the workings remained without system until 1874, when the general method of mining now in use was adopted. The output was gradually increased, as the Cambria Works grew, from an average of 120 tons per day in 1857 to 2,600 tons per day at the time of the explosion. All the coal produced is used at the works of the Cambria Steel Company at Johnstown. The mouth of the mine is in a steep hillside on the left bank of the Stonycreek River just above its junction with the Little Conemaugh, 42 feet above the river bed and 1,209 feet above tide. The thickness of cover on the coal, which is known as bed C, or cement seam, varies from a maximum of a little over 500 feet to a minimum of 70 feet over a small area where a mountain stream cuts partially through the measures. Over the greater part of the mine the cover exceeds 300 feet in thickness. The roof of the coal is generally a seam of tough slate, varying in thickness from 2 inches to 10 feet; over this is a quite compact sandstone about 15 feet thick. The remaining cover is shales, sandstone, coal and limestone in well-defined stratas of varying thickness. When the mine was opened no machinery was used and, owing to the difficulty of keeping the dip workings unwatered, nearly all the extensions were made to the rise until 1892, when an electric pump (abandoned in 1898) was installed to unwater the lower side of the mine. Mining in the dip was not extensive until what is known as the Klondike Section, where the explosion occurred, was opened in 1897.

The thickness of the coal varies from an extreme of 5 feet in the dip workings to a minimum of 3 feet on the hill headings and has a dip to the southeast averaging about 4 per cent. Local swamps and basins are occasionally encountered necessitating considerable pumping.

The system of mining followed is known as the "pillar and stall." The main heading is driven nearly on the strike of the measures and as a general thing the cross headings are driven directly to the rise or dip, as the case may be, and the rooms on the strike. In the Klondike district it

was found advisable to drive the main heading to the dip, the cross headings on the strike and the rooms to the rise of the seam. The headings are driven 15 feet wide, the rooms 27 feet wide and about 300 feet long, and the pillars between the rooms are left 30 feet thick with cut-throughs at least every 90 feet. The main heading into the hill is 3·35 miles long, which is practically the extreme length of the mine. The extreme width is 1·78 miles and the area mined out 2,300 acres, of which about 60 per cent. is on the right or to the rise and 40 per cent. on the left or dip of the coal.

Near the end of the main heading in the valley of Mill Creek, 3·1 miles from the mouth of the mine, there is a second opening and ventilating shaft, 10 x 23 feet and 77·3 feet deep. On the surface over one compartment, which is 10 x 10 feet, there is a Cappell blowing fan 16 feet in diameter by 5 feet face, run by a direct connected 20 x 18-inch horizontal engine. The boiler pressure is 120 pounds per square inch and the engine valve cuts off at about one-third stroke. The engine runs normally at 112 revolutions, forcing 130,000 cubic feet of air per minute down the shaft into the mine against a water pressure of about 2 inches. The other compartment of the shaft is fitted with a hoisting carriage, operated by a small pair of winding engines, to supply the power-house with coal, and a subdivision of it is fitted with easy steps and landings from bottom to top for use in case of an emergency. About 150 feet west of the shaft there is a power-house containing four air compressors, two low pressure and two high pressure, together with 1,200 horse-power water-tube boilers, with the necessary coal bins, pumps, heaters and an elaborate system of piping. The entire plant is modern in every way, the machinery is of the best, and the main building, which is substantially constructed of stone, steel, slate and concrete, is 43 x 162 feet in size. The low-pressure compressors furnish air at a pressure of 90 pounds per square inch at the power-house for use in the mine for mining machines and pumping. The high-pressure compressors furnish air at 900 pounds per square inch, for operating pneumatic locomotives, of which

there are four in the mine. The low-pressure air is carried to the face of each working-room and heading by 1¼-inch iron pipes laid from mains that are from 3 to 7 inches in diameter. There is about 95 miles of low-pressure pipe and 4 miles of high-pressure pipe used to convey and distribute the compressed air to and in the mine. There is also a second opening in the valley of the Stonycreek River, 1,100 feet south of the main entrance to the mine.

Near the mouth of the mine there is a power-house containing boilers and a pair of 20 x 30-inch tail-rope engines, used to haul the coal in trips of seventy cars each from the main siding in the mine, 7,300 feet from its mouth, to the tipple, a total distance of about 10,000 feet. All of the machinery and appliances in use are of the latest pattern and every precaution was taken to assure a thorough ventilation of the entire mine. The airways are all of large area and the velocities of the air currents are low. The air for ventilation is distributed through the mine in splits as required by the law of 1893. The Superintendent's office, the Mine Foreman's office in the mine, both power-houses and the tipple, have telephones and are connected through the exchange of the Cambria Steel Company with the city exchange. The Cambria Company has always been most liberal in providing machinery, tools and appliances to make their mines safe, modern and economical to operate. It has spared no expense to secure the safety of the employees, and with the precaution taken and with the large volume of air in circulation and the rigid rules enforced it was impossible to have such a disaster, except through the criminal recklessness or disobedience of an inside employee.

At the time of the explosion about 650 men were employed in and around the mine. Of these probably 580 were inside men and possibly 450 were in the mine at the time of the accident. The inside men who were not working that day were either on night turn or were idle for some cause. Including drivers and laborers there were in the Klondike at the time of the explosion about 150 men, working in three separate splits of air with a circulation respectively of 20,000, 18,000, and 8,000 cubic feet per minute.

When the Klondike Section was opened to the dip on the left, in 1897, a little gas had been found in the rib workings on the right or high side of the mine; but as the pillars were drawn back and the roof fell in and the area of the gob increased the gas had always disappeared. This was probably due to a more permeable strata of cover being exposed as the slates caved in and allowed the gas over the falls to escape through crevices to the surface. In fact, there was so little gas on the right-hand side of the mine that it was hardly considered, although fire bosses were always employed to look after the safety of the men. The face of the Klondike heading at the time of the explosion was 4,650 feet from the main heading. On the right side four pairs of cross headings had been driven off, practically on water level, and on the left there were five. All the work was opened originally on the double-heading plan, but after explosive gas was encountered the three-heading system was adopted where possible. A third heading or airway was sometimes made by utilizing the abandoned rooms next to and parallel to the main heading.

Of the two maps shown, the outline one is the entire mine at a small scale with the Klondike portion shown by the heavier shading. The other is a detail map of the Klondike. The star indicates the point of origin of the explosion, the crosses the location of the bodies found and the arrows the direction of the air currents. It will be noted (see map of Klondike Section) that between the fifth and sixth headings on the right side coming down there are about 2 acres of gob where pillars had been drawn; beyond this, toward the face of the headings for some distance, are abandoned rooms, then come working-rooms and then the faces of the headings.

All the walls that guide or confine the air were made of brick or slate and cement mortar; all air bridges were made of steel and brick; all important doors were in duplicate and the ventilation was considered to be without a flaw. The mine was always considered to be safe, as will be seen by the following paragraph from the report of the Chief of the Bureau of Mines for the year 1901:

"Ten mines are located in and about Johnstown; some of them are small, but all are well ventilated and drained, and consequently are in good sanitary condition. Five are operated by the Cambria Steel Company, all of which are equipped with the best kind of ventilators. The safety of the mines at this point can be judged by the fact that over 1,000,000 tons of coal were produced during 1901, and but one fatal accident occurred, that being in the Rolling Mill mine, the largest single operation in the district, which produced over 601,000 tons during the year."

EXPLOSION.

The explosion, which was not severe, occurred about 11.20 A.M. in No. 2 room of sixth right heading off the Main south or Klondike heading. There were two men working in the room and five others in the immediate vicinity, all of whom had been given safety lamps in the morning by the fire boss of that section, and were seen going into their rooms with them. The fire boss had made an examination of this place some time previous to 7 o'clock. He found gas as usual on the gob and recorded it in the daily report book at the office. As gas was expected and had been found in that locality for a long time, no precautions other than the usual ones, which were considered ample, were taken that morning. The fire boss had received special instructions some time before to note if the gas was getting stronger, but as he had said nothing about it and as the records, which he faithfully made, show no essential changes, it is safe to infer that the quantity of gas had not increased perceptibly for several months. This is confirmed by the mine foreman, who had examined the place the day before. As the fire boss in charge of this district, in company with others, went into the Klondike after the explosion and lost his life while aiding in the work of rescue, nothing positive concerning the condition of the gas on the morning of the explosion is known other than what is shown by his report book, the record in which was made about four hours before the explosion. The four fire bosses always entered the mine at 3 o'clock in the morning, and each of them examined

all the working places and roads of the district under his charge. They then went to the inside office, entered the result of their examination upon the book, reported verbally to the mine foreman and attended to giving out the safety lamps and getting the men started to work. After the men had all gone to their working places the fire bosses always made a second trip through their respective districts to see if everything was safe, and that all of the men who had been given safety lamps were working with them, and to note any dangers that might have arisen since the time of their first visit. This routine was observed on the morning of the explosion. The fire boss of Klondike and the others returned to the mine foreman's office from their second examination about 11 o'clock; but, as they made no further report to the mine foreman, and made no changes in the written report they had all signed in the early morning, the only inference that can be drawn is that they found everything in a safe and satisfactory condition. The fire boss in charge of the Klondike district was an elderly and especially trustworthy man, who had been employed by Cambria for many years. He had been assigned this more dangerous district on account of his known carefulness and ability, and had he found anything wrong or any unusual condition upon his second round he would undoubtedly have at once taken the men out of the danger and reported the fact to the mine foreman. As he did not do this and said nothing about any changed conditions, it is impossible to believe that he discovered anything out of the way on his second examination.

The men who were working in room No. 2, where the explosion originated, were German Poles, who spoke English fluently. All of them had been employed in Rolling Mill mine for a number of years, and as they had seen the danger constantly and their attention had been called to it frequently, it is impossible to consider them unfitted to work in that place. They had been selected especially for this locality only three days before on account of their superior intelligence and long experience in the mine, after a consultation of the fire bosses and mine foreman. The work of

drawing back the pillars from the sixth heading side, where the men were working, had been started only two days before and, as gas was known to exist, especially careful men were wanted to work in this locality. The seven men who were working there were in rooms Nos. 1 and 2 sixth right and rooms Nos. 1 and 2 long wall, and four of the seven were "butties" or partners. The explosion was felt at the mine foreman's office, which is at the entrance of the Klondike section, just as the four fire bosses were starting out of the mine. The mine foreman immediately sent word to them to come down into Klondike as there had been an explosion, and without a moment's hesitation they, together with the labor boss, mine foreman, assistant mine foreman, machine boss and an assistant fire boss, procured safety-lamps and went into Klondike to restore the ventilation and get the men out. The explosion was so slight that all who heard it at the mine foreman's office thought it was not serious, but to be on the safe side the mine foreman started his assistants to notify the men on the right-hand side of Klondike to go out. They found a number of doors blown down and while some of the officials were trying to replace them, and while others were endeavoring to warn the miners, the poisonous after-damp came upon them, and of the nine who went down, but two succeeded in escaping, and of the remaining seven, five lost their lives. The mine foreman and machine boss were removed from the mine unconscious and after a long siege at the hospital recovered. The fire boss of the Klondike district died in the hospital ten days after the explosion without at any time fully regaining the use of his faculties.

The result of the explosion was not disastrous to the mine. No damage was done except that all the doors on both sides of Klondike, of which there were twenty-one, were blown down and all the stoppings between the sixth and seventh headings and some between the fourth and fifth were blown out. The doors were not blown to pieces, but thrown down flat. The stoppings consisted of brick walls laid in cement, or of double walls 4 feet apart built of flat slate with the inside space filled with coal dust and the outside

plastered with cement to make them air-tight. The mine was damaged so little that cost of replacing all the doors and stoppings damaged or blown out and all other repairs did not amount to $1,000, and mining operations were resumed on the fourth day after the explosion. The only men that were burned by the explosion were the seven working in the vicinity of the body of gas. A few of the others were instantly killed by being blown against the pillars or gob, and the remainder were all suffocated by carbonic oxide gas.

A careful examination of the workings established the fact that there was a body of gas, which had been reported, on the gob between fifth and sixth right headings, which was probably nearly in its pure state, and when ignited in some manner by the criminal recklessness and disobedience of the men in No. 2 room, burned comparatively slowly, and as oxygen was not supplied in sufficient quantity for complete combustion, burned to carbonic oxide, of which authorities say one-half of 1 per cent. in the air will produce death in one-half hour. There was undoubtedly a very much higher percentage of this poisonous gas in the air which met the miners of Klondike as they tried to escape, as the most of them fell to the ground apparently without a struggle. The stoppings being blown down and the ventilation destroyed the poisonous gas advanced slowly through the workings and headings and cut off the escape of the men who delayed leaving their working places. The careful examination of the mine after the accident showed that the explosion was not complicated in any way by coal dust exploding. The coal contains but 17 per cent. of volatile matter, and dust as low in volatile matter as this is not apt to explode unless suspended in the air in large quantities and subjected to high heat and concussion. The Klondike portion of Rolling Mill mine was quite damp and there was little or no dust suspended in the air.

The greater number of the victims were found on their way out of the mine with their coats on and their dinner buckets in their hands. Those working on the left side of Klondike and in the fifth heading on the right side of

Klondike, after they heard the explosion, carefully put their tools away, put on their coats and leisurely walked out of their rooms into the poisonous atmosphere. One miner testified at the inquest that he was working in a room off the fifth right heading when the explosion occurred; the concussion of the air knocked him down and extinguished his lamp, but he relit it and went back to work. Shortly after one of the fire bosses, who later lost his life, came in and ordered him to go out of the mine at once, which he did, but had a very narrow escape. On the left side of Klondike there were about sixty-three men working; among them were three pair of brothers, Americans, English and Irish, and all very intelligent men, who operated mining machines. Some time after the explosion when the air commenced to get bad, they opened the low pressure air pipes with their valve keys, so that the compressed air would blow into the faces of three rooms, and tried to get the men into these rooms, where they would be in the pure air that came from the pipes. This air was carried in the pipes at a pressure of something less than ninety (90) pounds per square inch, and it is estimated that nearly five times as much air came from the three open pipes as was necessary to preserve the lives of all these men. It was the next afternoon before the rescuing parties were able to get into the left side of Klondike, where they found only fifteen of them alive. Those still living were found at the end of the air pipes, the others, dead or dying, were found all sitting or lying at the mouth of Room No. 17 on the fourth left. Why these men left the faces of the three rooms where there was plenty of pure air and went into the poisonous gas on the heading is inexplicable. A number of them who were rescued were questioned, but their stories disagreed, so that it is impossible to draw conclusions that will satisfactorily explain their action. The men working in the other districts of the mine did not hear the explosion and did not leave the mine until ordered out by the officials, or until they discovered through not getting cars to load that the mine was shut down. Had the concussion been more severe it is very probable that it would have been so alarm-

ing that all of the men working on the left side of Klondike would have hastened from the mine without delay, and thus probably reduced the appalling death list by perhaps two-thirds.

It is a mystery what caused the gas to come in contact with the naked lamps in Room No. 2. It would be possible to account for it by an extensive fall of roof over the gob, but an examination after the explosion showed no fall of magnitude, and as it was shown that the miners working with naked lights had no occasion to go into the gob, the ignition of the gas will probably forever remain a mystery. The mine inspector had examined the mine on the 2d of June, five weeks before the explosion, and could find no fault with it in any way, and made a flattering report of its condition to the Chief of the Bureau of Mines.

THE WORK OF RESCUE.

The officials in charge of the Mining Department of Cambria received word of the explosion a little over one hour after it happened, but the magnitude of the calamity was not known until after they had gotten into the mine and met the after-damp on the main heading coming out with the air. When the extent of the disaster was realized the other mines of the Cambria Steel Company at Johnstown were at once stopped and the foremen and bosses, together with the competent English-speaking men, were rapidly driven to the escapement shaft at Mill Creek, 7 miles, to aid in the rescue.

Promptly after the explosion the fan was by telephone orders speeded up to 220 revolutions, forcing about 250,000 cubic feet of air per minute into the mine. Men were kept at the bearings and oil was used freely so that none of the bearings of engine or fan were unduly heated. The compressors were kept running constantly and the pressure in the two air-pipe systems maintained at 90 and 900 pounds per square inch respectively until the third day after the explosion, when the mine had been fully explored. This precaution undoubtedly resulted in the saving of the lives of

the men in the fourth left who remained in the faces of the rooms where the air-pipes were open.

When the officials of the Cambria Steel Company reached the mine and grasped the situation, brattice cloth, tools, and physicians with cans of oxygen, were immediately ordered and the work of rescue begun in a systematic way. The first regular rescuing party, led by the superintendent, went in the Klondike with physicians and cans of oxygen at about 4 P.M., and pushed ahead of the parties who were putting up brattices, to restore the ventilation. They succeeded in reaching some of the men on the Klondike heading who were still living, and by a liberal use of oxygen, quick trips to the hospital and faithful work on the part of the physicians and nurses, a number were resuscitated. Others were too far gone. The first efforts were to find the living; no attention was given to the dead other than a hasty examination. When life was found to be extinct the party passed on, searching for the living. Others were engaged in stretching brattice cloth and putting up stoppings to restore the ventilation as far as possible. This work was continued systematically night and day until the entire Klondike region had been thoroughly explored. Several attempts were made to enter the left side of Klondike the night of the 10th and morning of the 11th, but the air was in such a condition that it was impossible to live inside the entrance of the cross headings, and it was not until the afternoon of the 11th that a rescuing party, headed by the superintendent, succeeded in finding the men who had collected in No. 4 heading. There were physicians with cans of oxygen with all the rescuing parties and a number of lives were saved by their efforts in the mine. The last bodies removed from the mine on the evening of the 12th were four that had been located on the night of the 10th, but, owing to the rescuers confusing two of the heading numbers, had not been moved. There were about 150 men working in their places in the Klondike at the time of the explosion; of these about 100 lost their lives, 50 escaped, and the remaining 12 are accounted for by the lives lost in the mine foreman's party and by the fact that a number of laborers

went into Klondike after the mine foreman and his party to help restore ventilation. There was circulating in this portion of the mine about 46,000 cubic feet of air per minute, or more than 100 per cent. in excess of the requirements of the mine law.

The Board of Mine Inspectors appointed by the Chief of the Bureau of Mines of the State made a thorough examination of the mine on the 13th, or the third day after the explosion, and on the two following days. In room No. 2, sixth right heading, on their first trip, they found two common miner's lamps and a miner's cap lying near the face of the workings, and another party found shortly after the explosion, while the bodies were being removed, two safety lamps standing alongside of the road, not far from the face of this room, that had evidently been placed there before the explosion. About two months after the inquest a driver made affidavit to seeing the two men in Room No. 2 working with naked lights about ten minutes before the explosion, but he did not report the matter. During the investigation this driver was probably afraid of getting into trouble for not reporting such a gross violation of the Mine Law, so this evidence was not brought out at the inquest.

THE INQUEST.

Shortly after the accident the Coroner impanelled a jury, and the bodies were viewed at the morgue, as required by law. The inquest began on July 23d, and continued for five days. During that period there were thirty-four (34) witnesses called. The investigation at once took a very wide range, and many of the older miners and employees who were familiar with the conditions in the mine, both before and after the explosion, and many others, and all of the mine officials were called upon to testify. It was clearly established that the men working in the rooms where the explosion originated were given locked and lighted safety lamps that morning and took them into their rooms. It was also shown that no defective safety lamps were ever given out, and that no unlocked ones were given out except to experienced men who were authorized to fire blasts.

The last witnesses called were the four mine inspectors, constituting the board that had been appointed by the Chief of the Bureau of Mines to examine the mine to determine and report upon the cause of the explosion. Their report showed conclusively the point of origin of the explosion and its cause. Their testimony and the report was based upon three careful examinations of the mine after the explosion, and the facts observed during the frequent visits of the inspector of the district in which the mine is located. They discovered conclusive evidence that the mining laws and rules of the company had been deliberately and wilfully violated by the men working in room No. 2 sixth right heading, and stated so in their report, which was very complete, impartial and thorough, and showed careful attention to all the obtainable facts relating to the management and operation of the mine and all the conditions surrounding it. The general testimony showed that all of the mine officials and foremen were without exceptions experienced, sober and competent men, holding certificates of competency, and that they all knew of the dangers generally surrounding mining operations, and that they had always fully realized the responsibilities resting upon them. The jury, after deliberating carefully, returned the following verdict:

"We find that these persons (naming them) came to their death as the result of an explosion: that said explosion was caused by person or persons to the jury unknown by taking into room No. 2 sixth right heading, where gas was known to exist, open lamps, and using same in direct violation of the mining rules and regulations of the Cambria Steel Company."

It was shown during the inquest that the Cambria Steel Company had, through their officials, taken particular care to guard against the dangers that might arise in the mine from gas or other causes. Copies of notices calling the attention of each individual man in the mine to the dangers connected with explosive gas were shown, and it was further shown that every inside man had received one of these notices printed in the language with which he was most familiar. A large mass of correspondence between the management and the mine officials, extending over a period

of nearly three years, was shown, in which the mine officials were constantly urged to take every possible precaution for the safety of the men, and were instructed to make any demands upon the company for supplies, machinery, appliances or tools needed to make the mine safe and healthful. Some of the letters called attention to accidents at other mines, and pointed out the lack of attention and care brought out by the different Coroners' inquests held on the bodies of men killed in mine explosions, and cautioned the mine officials against taking risks or hesitating at any expenditure necessary to make the mine safe. These letters were all written in such a way as to bring replies and acknowledgments from the mine officials to the management, showing that they thoroughly understood the conditions and were taking all precautions possible, and that they all realized their responsibilities, and that their first duty was the safety of the men, and that in case of any doubt they were always to take the safe side if it closed the mine down at once.

The only precautions that have been used since the accident that were not taken before, are the absolute prohibition of the use of naked lights in the Klondike region. This portion of the mine is now operated exclusively with safety lamps, but it is only by extreme watchfulness that it is possible to keep naked lamps out of it and make the men strictly obey the rules. One miner was detected smoking in the Klondike in a dangerous place within three months after the explosion, and is now serving a sentence in the county jail for his violation of the mining law.

Each of the victims of the explosion carried one thousand ($1,000) dollars insurance in the Cambria Mutual Benefit Association, whose accounts are guaranteed by the Cambria Steel Company, which was paid to their families in addition to burial fees. A subscription was started and a small fund collected for the dependent families, but it was quickly seen that it was unnecessary, as their temporary wants were all provided for by the Cambria Steel Company, and the insurance money would be paid to them as soon as the necessary legal formalities could be complied with.

I have outlined as briefly as possible in the above the essential facts relating to this terrible disaster, and can only add that there will probably be such accidents, of a more or less serious nature, as long as only human beings are depended upon to work in the mines. Every precaution was taken at this mine that could be thought of to prevent a disaster, but the inexcusable disobedience of the strict rules by one employee resulted in his death and that of over one hundred of his fellow-workmen.

JOHNSTOWN, PA., April 6, 1903.

MECHANICAL APPLIANCES AT BLAST FURNACES.

The use of mechanical appliances for handling raw materials and fuel at blast furnaces, and of casting machines for the iron product, has made such an advance that it is estimated by good authority that a modern furnace can turn out 10 tons of finished product with the same number of workers that was needed to turn out 1 ton forty or fifty years ago.

PRECIOUS METALS IN THE ARTS.

One of the difficult problems to solve is the determination of the quantity of gold and silver used in the arts. The statistical departments of several European countries have tried to solve this problem, and have given it up. The U. S. Treasury Department has for several years endeavored to get accurate statistics on this point, but its figures are still far from complete, chiefly because it is impossible to determine the quantity of coin melted by jewelers and others. There seems to be a special secretiveness developed among those who use gold and silver in their trades.—*Engineering and Mining Journal.*

TWO NEW ELEMENTS?

Dr. Baskerville, whose position as professor of chemistry at a prominent Southern university entitles his utterances to every consideration, recently announced that he had discovered what are probably two new elements associated with thorium, both of them radio-active. The two new substances have been christened carolinium and berzelium. Samples of the substances isolated by Professor Baskerville have been sent to Sir William Crookes, who will doubtless confirm or disaffirm the assertion that they are new elements.

The importance of the discovery, if it should ultimately appear that the two new substances are elements, can hardly be overestimated; for the number of radio-active substances is now increased to about six. Sir William Ramsay is reported as having every confidence in Dr. Baskerville's announcement.—*Scientific American.*

Mechanical and Engineering Section.

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Experimental Work with Solid Emery Wheels.

By T. Dunkin Paret.

The commercial literature of mechanical goods has steadily improved. The improvement of the literature has probably been as great as that of the goods. Each year catalogues and advertisements have become more precise. They fairly bristle with tabulations and data. The automobile, gasoline launch, dynamo, turbine wheel, steam boiler, engine and 12,000-ton armor-clad are all exploited in delicate half-tones, on expensive paper; but side by side with the pictured show goes a guaranteed statement as to actual performance.

To this improvement the literature of the solid emery wheel is an exception. That literature swells with adjectives and generalities, and is over-weighted with broad, unspecific claims. Every emery-wheel maker in America makes "the best wheel." These wheels are sharp, cool and free-cutting, and generate no heat. They work equally well wet or dry. Some of them are composed entirely of mineral substances, so that everything cuts. Some of them are noted for open texture—you can even blow through them! They are nearly all noted for their durability.

All wheels being thus equalized in the advertisements, the buyer thinks one wheel as good as another, and either changes carelessly from one make to another, or guides his choice by the biggest discount.

The presumptous demander of definite data would certainly receive none. It is a singular fact that the buyer rarely seeks data. Occasionally a very green one asks how long a wheel ought to last. As he does not give the size of the wheel, nor the speed he intends to use, nor the pressure he means to apply, nor the metal he desires to grind, nor

the number of hours per day the wheel will run, it is manifestly impossible to answer his question.

On the one side the buyer has no guarantee nor definite data as to the performance of the wheel he buys, and, on the other side, the seller has no certainty as to the conditions under which his wheel will be used. Thus results recrimination. The buyer complains that his wheel is a disappointment and that one wheel is as bad as another. The maker retorts that no wheel can be expected to do well which is run under improper conditions in defiance of the maker's rules.

In this state of affairs several questions clamor for answer. Is one wheel as good as another? Is it safe to buy at random and to place equal value on all wheels? Is there any method by which the buyer can ascertain the relative value of wheels? Is there any reason why emery wheel catalogues and advertisements should not supply definite data?

A very recent experience throws some light on the question as to what chance an inexperienced buyer would have in his first attempt to buy a good emery wheel. As preliminary to experimental work by the writer of this paper, five emery wheels were ordered directly from five different manufacturers. The factories which supplied these wheels were all long-established ones, popular and of excellent repute. The orders indicated the number of emery, and called for the wheels best suited to general machine-shop work, for hand-grinding on cast iron.

Tested under conditions practically identical, the results were so widely different as to demonstrate beyond doubt that there was only one chance in five of getting a good wheel. One wheel ground off $12\frac{50}{100}$ ounces of cast iron in 4 minutes, but lost $16\frac{18}{100}$ ounces of its own material in so doing. A second removed $13\frac{26}{100}$ in 4 minutes, with a loss of $15\frac{62}{100}$. A third removed only $6\frac{81}{100}$ in 4 minutes without apparent loss of wheel material. A fourth broke badly after only 40 seconds. A fifth removed $13\frac{81}{100}$ with a loss of only $1\frac{81}{100}$.

If an inexperienced man had bought these wheels in the

consecutive order here indicated, he might well have given up in disgust his search for a good wheel. The first two wheels were entirely too soft for this test, and lost about one-eighth of their available substance in 4 minutes. The third and fourth wheels were as much too hard for this test as the first and second were too soft. The fifth was "a good wheel." It removed a reasonable amount of metal with a minimum loss of wheel material.

The citation of these figures, however, is but a partial explanation. Though the great defect of emery-wheel literature is its lack of definite tabulations, it is a fact that mere numerical data are misleading. Such data must be supplemented by the oft-repeated observations and deductions of those practically familiar with emery wheels. It is not enough to say that the first two wheels were too soft. It must also be pointed out that at the end of 4 minutes each wheel was worn out of shape, and that, in consequence, the bar was being ground to irregular shape. It must also be shown that the tabulated loss of wheel material does not indicate the eventual sum. Great additional loss would accrue when the wheel was turned so as to have a square face, and still further loss would occur in the useless hub. Besides this great eventual loss of material, not indicated by the tabulations, there is a further loss due to the repeated turnings or truings of the wheel and the labor thereby incurred. Of great importance also is the fact that, at such rapid rate of wear, correct work could only be done for a few seconds at a time.

If the over-hard wheels were to be valued by the numerical data only, a great error would result. It is said of the third wheel that it removed $6\frac{81}{100}$ without apparent loss of wheel material. The truth was that at the end of 4 minutes this wheel weighed $\frac{12}{100}$ of an ounce more than at the beginning, notwithstanding the fact that its edges were badly broken. This gain was due to the metallic coating which flecked it heavily over.

No mere numerical table or chart of curves can be made to include the many and varied mitigating elements and collateral circumstances connected with an emery wheel

test. To estimate the value of this third wheel we should have to determine the real loss of wheel material as contrasted with the apparent loss. This loss would depend on the weight of the broken edges, and the weight removed in the numerous turnings necessitated by rapid and heavy metallic glazing. To still further complicate the problem, it must be pointed out that the tabulated metal removal is affixed to a 4-minute period. None but a critical experimenter will realize the fact that this wheel's best cut was at the start, and that metallic glazing is accompanied by a lessening product. The problem to be solved is as to what will be the average minute removal for a day's work if the average for 4 minutes is $1\frac{70}{100}$ ounces per minute. Then, again, the fact is to be considered that flying edges might destroy the sight, and that they clearly indicate a dangerous tendency.

The defects which characterized the third wheel were intensified in the fourth. This wheel broke badly at the end of 40 seconds and was very heavily coated with metal. This experiment (being restricted to 4-minute tests) affords no evidence as to product and wear under continued use. Such evidence can be supplied by reference to an older investigation.

Under date of September 9, 1891, Coleman Sellers, J. E. Denton and Alfred R. Wolff made a "Report on the Comparative Value of Fifteen Varieties of Solid Emery Wheels." This report states that eleven (out of fifteen) varieties were slow cutters, and it contains a striking paragraph as to the two varieties for which it claims pre-eminence. This paragraph reads as follows: "One striking feature characterized these two; that is, that in every series of trials these wheels increased in productive capacity, the average of the last cuts of all the series being greater than the average of all the first cuts. The thirteen other varieties all decreased in productive capacity, the average of the last cuts being less than the average of the first. Some of those which made a brilliant show at the start cut scarcely anything at the close."

This loss of productive capacity is largely due to that

metallic glaze which characterized wheels 3 and 4 in this later trial. This glaze, which is almost steadily cumulative, affects both the cutting capacity of the wheel and its safety. The wheel which glazes badly is likely to burst. In conducting some of these experiments at night, the progressive glazing became visible. When a wheel of this character first began to grind it was surrounded with a halo of brilliant, corruscating, white sparks. Through these a very narrow cherry-red line came slowly into sight, and this line grew and widened into a cherry-red ribbon. This ribbon indicated the increasing band of metallic glaze, which band, though formed of discontinuous blotches and flecks of adhering metal, appeared, at that speed, like a continuous ring. It was soon noticed that if this ring grew and widened rapidly the wheel broke or burst before the end of the test.

This fact has significant bearing on the question as to whether certain makes of wheels are inherently safe and other makes dangerous. It also demonstrates the fallacy of tests restricted entirely to speed. One such test has recently been made under circumstances which give it special prominence. There was (apparently) in Germany such general distrust of solid emery wheels that these wheels, either from custom or legislative restriction, were run at a speed too low for effective work. With the view of altering these conditions a series of trials was inaugurated by the Association of German Engineers, and carried out by Prof. M. Grübler, of the Technical High School, Dresden. His preliminary report was dated May, 1902. In these trials the solid emery wheels were run free, and the only real result was to determine the maximum bursting speed. Nevertheless, the wheels are classed (as to their binding material) as vegetable, mineral, chemical, unknown and animal. It seems evident that the wheel with the highest maximum bursting point was to be considered the strongest, and that the nature of its binding material was to be considered only with reference to its cohesive quality.

This German trial demonstrated the fact that nearly all the wheels could endure the standard American speed; but this fact had long been patent to American makers and

users of solid emery wheels. If solid emery wheels were to be run free, this trial would have some value; but wheels are intended for practical use, and their probable behavior under such use is the chief matter of inquiry.

The American trials reported in 1891 are eminently practical, as compared with this German one. The American investigators agreed as to the qualities which constitute "a good emery wheel," and these were stated to be: "Safety under the widest conditions of use and misuse; rapidity of cut; freedom of cut at moderate pressure; reasonable amounts of wheel loss and power consumption; evenness of wear; general staying quality, and reliability under the widest range of circumstances."

To demonstrate these qualities it was necessary to elaborate a process and to invent a machine. The report states that "This machine was so constructed that the wheel and work were brought in contact by definite and measurable pressure, without any obstacle being interposed to the free wear of either metal or wheel. The results approximated closely to those obtained by hand pressure, and yet were independent of all influence from the operators of the machine." These words were written many years ago, and they apply with still greater force to the more modern machine and process used in the experimental work which is the special subject of this paper.

The makers of the over-soft and over-hard wheels (1 to 4) might object that the machine and process which produced such opposite and unfavorable results were not suited to their wheels, and did not conform to that requirement of the order which specified that the wheels should be those best suited to general machine-shop work, for hand grinding. To this objection the answer is that while the machine and process are not identical with handwork, they assimilate closely to it. The characteristics of general hand grinding are intermittent contact between wheel and work at irregular intervals of time under pressure unknown and variable.

For this the new process substitutes intermittent contact at regular intervals under known and uniform pressure.

Before deciding as to this pressure the ordinary method of a skilled grinder was observed, and the deflection under pressure of the bar used to grind on was carefully noted. The same deflection being then reproduced by the attachment of weights to the bar, the actual pressure was obtained. Long experience, both previous and subsequent to this report, confirms the fact that it is an easy and customary thing in hand grinding to attain the pressure at which wheels 1 and 2 wore out with undue rapidity, and 3 and 4 glazed and broke.

If all makes failed at this pressure and under this process, it might justly be claimed that the test was not fair; but as wheel 5 stood the test, and as still other makes have stood it repeatedly, it seems fair to approve the one class and to condemn the other.

Wheel 5 removed $13\frac{81}{100}$ ounces of cast iron in 4 minutes with a loss in wheel material of only $1\frac{81}{100}$ ounces. These figures are suggestive, but neither figures nor charted curves would tell its true story. It must be also taken into account that this wheel had no broken edges, that its face remained square and true, and that it showed not the slightest adherence of metal. It would be a big jump from this 4-minute test to the conclusion that wheel 5 was a perfect wheel; but subsequent trials with this same wheel and unnumbered trials with wheels of the same make, and with others of similar quality, confirm the inference that wheel 5 is one of a class inherently sound and good, as contrasted with other classes, some of which are inherently dangerous and all defective.

It may be claimed that the wheels here classed as oversoft and over-hard are only proved so by their failure under this particular process and on this particular machine, and that at pressures adapted to them they would work to satisfaction. It is possibly true that, under lighter pressure, wheels 1 and 2 might have made a better showing, and that wheels 3 and 4 might not have broken so readily. Such necessities of careful adaptation do not characterize wheel 5 nor other wheels of similar general quality. Wide experience shows that such wheels are safe under the widest con-

ditions of use and misuse, and are reliable under the widest range of circumstances.

Attention is asked to the assumption of inherent safety and inherent danger. Is this assumption correct? The inferences from the preliminary German report are that the safety of a solid emery wheel depends on its ability to withstand the disrupting strain of centrifugal force and that the cohesive strength of its binding material is the all-important element. This report shows, however, that the minimum bursting point of the fifty-four wheels (of nineteen varieties) tested was at more than double the usual standard American speed, and that the average bursting point (in revolutions per minute) was at more than three times the customary American speed. The correct inference is that nearly all wheels have a wide margin of safety so far as speed and centrifugal force are concerned, and that the safety of a wheel in use demands other qualities than cohesiveness.

The ordinary observer is apt to infer freedom of cut from the open texture of a wheel and to argue that such a wheel will generate little heat. The commercial literature of the emery wheel perpetuates several erroneous ideas on this and other points. It suggests that gums, glues, cements, etc., are used in some makes as a binding material, and that these substances completely fill the interstices between the emery grains, thus creating a close instead of an open texture and interposing a non-cutting substance between the mineral grains. It is argued that if each of these grains is surrounded with a non-cutting substance, it cannot itself cut to advantage. The superiority of wheels entirely mineral is proclaimed, and a typically good wheel is said to be one in which mineral grains are so united at the corners as to leave plentiful and relatively large interstices.

The mere appearance of an open-texture wheel is attractive, but this appearance is delusive, as is also the theory concerning texture. Nothing save repeated experiments and long experience can demonstrate which make of wheel is inherently free-cutting and safe; and, when demonstrated, it is not easy to see why one make possesses good qualities

and the other lacks them. Experience and experiment do both demonstrate the fact that the best wheels are of close texture. It is possible that the pores of open-texture wheels may be too ready lodging places for dust and débris, and that heated metal, forced into such interstices, may mat and bed and cling, while, on compact wheels, it would fail to adhere. It must be noted, also, that vitrified and silicate wheels (all wheels, in fact, which are entirely mineral) are incombustible. On the other hand, wheels whose binding material is gum, glue or other organic matter are readily affected by heat, and as the interstitial matter chars and crumbles, fresh surfaces are steadily and persistently exposed.

It is a fact, therefore, demonstrated by countless experiments and long experience, that certain makes tend to fleck or flake over with adhering metal, and that this adherence lessens their productive capacity, and also makes them unsafe. Whether this is due to texture, to chemical composition or to their quality as conductors of heat, is uncertain.

One most important fact, not indicated by charts or tabulations, is that which concerns the proper cutting surface of a wheel. The acceptance of poor wheels and the condemnation of good ones is caused by a mistake on this subject. Every wheel, as sent out by its maker, has an unnatural artificial surface, and, as a rule, it is by this surface that the wheel is judged. A new wheel is offered for trial, and if it starts off with a rush, cutting rapidly and brilliantly, is accepted after the test of a few minutes. The rapid cut may be due, and often is, to the roughness of a hacked, dressed or artificially procured surface, and the wheel may steadily deteriorate or settle down to a slow cut. Another wheel may be too smooth, and make but a poor show at the first. The operator is likely to be impatient and condemn this wheel, yet it would almost surely increase in product after reasonable time and greatly surpass the execution of the brilliant first-minute cutter. It is a good rule, steadily advocated by one firm of wheel-makers and observed by very few operators, not to accept or condemn any wheel

until by actual work in grinding its diameter has been reduced at least $\frac{1}{4}$ of an inch.

In view of this fact it is a great error to use too frequently the emery wheel dresser, the diamond point or the hacking tool. A poor wheel which quickly flecks over with metal may require this; but such requirement, with its necessity for useless labor and its steady consumption of wheel material, is enough to condemn any wheel. A good wheel does not require it, and, every time that such a wheel is dressed, time and material are wasted and an artificial surface substituted for a natural one.

In order to lead up to recent experimental work it seems best to reproduce a few facts from the investigation reported on in 1891. In that test seventy-eight wheels were employed and fourteen of them burst. One hundred and ninety-three trials were begun and only 136 completed. The average metal removal per minute at a pressure of 112 pounds per square inch was 1·409 ounces. In calculating the loss of wheel material no account was taken of the wheels which burst, nor was the real loss of material correctly ascertained in the case of those wheels which glazed heavily. Fifty-seven trials were begun, which, from unstated causes, were not completed. As fourteen wheels burst, it follows that forty-three tests failed from other causes. These failures have a strong bearing on the question of staying power and general reliability. Sometimes these wheels wore out of true to such an extent that the bar could not be kept in proper contact. Sometimes they threw belts off the pulleys. From various causes the machine was stopped, the process brought to a standstill and valuable time wasted.

Comparison of the old and new trials demonstrates the fact that definite qualities are permanently attached to different makes. In the preliminary test of 1903 wheel 3 removed only $1\frac{70}{100}$ ounces per minute, while wheel 5 removed $3\frac{45}{100}$. In the test reported in 1891 the prototype of wheel 3 (a wheel of the same make) removed only $\frac{47}{100}$ per minute, while the fellow of wheel 5 removed $1\frac{92}{100}$. It cannot be chance which, at an interval of fifteen years, shows one make to be good and another bad.

Inasmuch as a valuable result of every investigation is that general experience which cannot be tabulated, the extent of the investigation is a matter of importance. Inferences, deductions and theories are of little value if they depend on a few observations. If the number of observations is great and the results correspond with those of other investigations, the inferences are correspondingly safe.

The investigation of 1903 and 1904 comprises 194 finished tests of 4 minutes each, or 776 distinct tests, and a certain number of incomplete tests which also throw light on the subject. The wheels used came from seven different makers, and were forty-eight in number, of thirty distinct varieties. The average diameter of these wheels was about 9½ inches, and the average revolutions about 2,250. The metal consisted of bars ¾ of an inch wide and ½ inch thick. Tests were made at various pressures, but those at 112 pounds per square inch are considered the most instructive. At this pressure 244 1-minute tests were made on cast iron, thirty-six wheels being used, of twenty-six classes or varieties. The metal removal averaged $2\frac{67}{100}$ ounces per minute, and for each ounce of metal ground off $\frac{17}{100}$ of an ounce of wheel material was consumed.

Towards the close of this investigation three classes were selected, as being among the fastest cutters, and subjected to special trials. At 80 pounds pressure per square inch, the average minute removal of cast iron was $3\frac{9}{100}$ ounces, and the wheel loss $\frac{29}{100}$. At 110 pounds the metal removal increased to $5\frac{88}{100}$, with a wheel loss of $\frac{67}{100}$. These cuts illustrate what may reasonably be expected from a good wheel.

This investigation was expected to cover wrought iron and tool steel, but so much time was employed on cast iron that equal series of trials could not be completed. Some deductions can be drawn from the unequal series, but the averages are not so trustworthy as in equal series. It may be stated, in a general way, that wrought iron and tool steel are ground off much more slowly than cast iron, and that they are more destructive to the wheel. In fifty-two

1-minute tests on wrought iron the minute removal averaged $1\frac{8}{100}$ ounces, while for each ounce of metal removed $1\frac{8}{100}$ of wheel material was consumed.

An attempt has been made to arrive at the cost of grinding both on cast and wrought iron, and also at the cost of filing, but it must be remembered that the conclusions which are drawn from very unequal series are not altogether sound. In arriving at these costs, a wheel 10 x 1 is assumed to weigh $7\frac{3}{4}$ pounds and to cost $1.65—that is, 75 per cent. discount on a list price of $6.60. Labor is calculated at the rate of $1.75 for a day of ten hours. No allowance is made for power. Under these conditions, and counting only the cost of wheel material and the actual time of grinding, at a pressure of 112 pounds, it costs $5\frac{26}{100}$ cents to grind 1 pound of cast iron and $27\frac{53}{100}$ cents for the same quantity of wrought. This cost, so far as it refers to cast iron, is derived from the 244 minutes test of thirty-six wheels. It is interesting to note that the few trials of specially fast cutters show a diminished cost. This diminished cost (on cast iron) is almost the same at 80 and 110 pounds. At 110 pounds the cost of material is greater than at 80 pounds, while the cost of labor is less. At 80 pounds the total cost is $3\frac{49}{100}$ cents per pound; at 110 it is $3\frac{52}{100}$.

A few tests were made with the file on bars furnished for the grinding test, three different machinists being timed. These gave a cost per pound of $29\frac{90}{100}$ cents for cast iron and $74\frac{78}{100}$ cents for wrought. The minute removal by the file for cast iron was $\frac{15}{100}$ of 1 ounce; for wrought iron $\frac{8}{100}$.

To throw light on this recent investigation and on its relations to practical work, the data of a much older test are here reproduced. The new test machine and process will be objected to by some as not corresponding to shop practice. These same objectors would probably condemn a hand-test, because the personal factor throws doubt upon it. It is interesting, however, to see how far old tests, made by hand under very different conditions, compare with the modern ones.

The old tests (made under the supervision of the writer of this paper) were described in *The Railroad Gazette* of May

27, 1887. The grinding was done with a wheel 14 x 2, cast-iron bars 3 feet long, 2 inches wide and ½ inch thick being employed. The product decided upon as a fair average was $4\frac{13}{100}$ ounces per minute at a cost of $5\frac{80}{100}$ cents per pound. This cost was based on the much higher prices then asked for emery wheels and on a higher rate of wages. Calculated on the same basis as that of the recent test, the cost would be $2\frac{87}{100}$ cents per pound. This cost is still lower than that due to the use (in recent test) of a free-cutting wheel at 110 pounds pressure.

While it is not entirely safe to draw conclusions from tests so widely different, it may be pointed out that, in the recent test, the metal surface in contact with emery wheel measured only ⅜ inch by ½ inch, while in the old tests (hand grinding) the area of contact was 2 inches by ½ inch. While hand tests (as matters of comparison) are unsatisfactory, because the pressure is an unknown quantity, it is quite certain that 110 pounds per square inch can easily be attained by the use of a 3-foot bar. Another unknown factor in this particular problem is the difference in product due to difference in diameter of emery wheel. It is claimed in a general way by some that wheels of large diameter are better grinders than those of less diameter. Data on this point seem to be entirely lacking, though their value would be great. It is possible that the decreased cost shown in the hand tests may be due to the use of a wheel of large diameter.

In this same old hand test the cost of grinding wrought iron is figured at $21\frac{20}{100}$ cents per pound. The cost of filing cast iron is put at $35\frac{90}{100}$ and of wrought iron at 75 cents.

As bearing on the rate of product, it may be stated that the minute product of the fastest cutter was 7 ounces, and of the slowest cutter only $1\frac{25}{100}$ ounces.

One striking fact is brought out by these old tests, and this is that the emery wheel (even in hand grinding) maintains its rate of product far better than the file does. In a half-hour test (by wheel) the minute average was only 16 per cent. less than the best cut made. By file test the minute average was 49 per cent. less than the best cut.

While part of this decrease is due in both cases to fatigue of the laborer, it is due in greater part to steady deterioration in the cutting power of the file; and the longer the test the more unfavorable would be the results of the file.

Another comparison between wheel and file may be referred to with advantage. In *The Iron Trade Review* of March 28, 1889, the comparative products of wheel and file are set forth pictorially. The pictures show the exact size and shape of cuts made in cast iron and saw steel by wheel and file. The data prove that, under ordinary shop conditions, the wheel ground (on saw steel) 16½ times as much as could be filed off in the same time, and, under far better conditions, 126 times as much. The steel used was No. 9 wire gauge (American standard); that is to say, about ⅛ inch scant, or 3 millimeters thick. In 30 seconds the wheel ground a slot 1⅛ of an inch wide by 4¼ inches deep. The slot made by a new file in 60 seconds was only ½ inch wide by ⅛ inch deep.

It is a difficult task to draw correct deductions from numerical data listened to, as this paper is, and even the expert may find cause for long study in the printed tabulations. These details barely suggest certain facts which the experimenter appreciates in part and around which there are many doubts only to be cleared up by much more thorough investigation.

Under all these investigations is hidden the as yet unexplained factor of heat. Heat is the great underlying, uncalculated and often unsuspected factor in emery wheel accidents and also in emery wheel product. In old times wheels were occasionally made so lacking in cohesiveness (so rotten) that they flew to pieces merely from the centrifugal strain. Such cases are extremely rare nowadays. In some cases wheels of proper coherence are burst by the sudden application of excessive pressure, as when a piece of metal gets jammed between the wheel and the machine rest, or as when a strong man applies the leverage of a long bar. Occasionally, wheels are unsafe owing to some crack undiscovered at the time of shipment, or produced afterwards during transit or use. The main cause, however, of bursting wheels is heat.

Just how heat operates is somewhat of a mystery. The conclusion seems natural that wheels which are poor conductors of heat are the most unsafe. In such wheels the heat created by friction at the circumference works slowly towards the center, and the outer rim expands with speed disproportioned to that of the center. Such expansion might result in cracks transverse to the face and other cracks radiating from face to center. As a matter of observation, the wheels which are unsafe are those whose substance conducts heat easily, and which quickly get hot all through. Such wheels throw off broken edges and irregular chunks, and burst entirely without any definite system of cracks.

It follows from this that wheels entirely mineral are not, as a class, so safe as those in which the mineral grains are surrounded and separated by gums, glue and other organic matter.

The adhesion of metal to the surface of the wheel is also, to some extent, an effect of heat. It may be that wheels with this defect overheat and soften the metal, or the adhesion may be due either to the chemical constitution of the wheel or its physical structure. It is a clearly ascertained fact that free-cutting wheels are not characterized by such adhesion, and that slow-cutting wheels are. It is also evident that as the metal increases in heat the cut (or product) decreases. It is seldom that the end of a $\frac{5}{8} \times \frac{1}{2}$ cast-iron bar is much reddened by the grinding of a free-cutting wheel, and the edges of the bar are generally clean-cut. Under the same conditions wrought iron gets red-hot for a considerable distance and flattens out and bends over at the edges.

Many years ago an experimental test machine was built in which the metal was forced against the wheel by a continuous screw feed. As the bar elongated with heat, the pressure increased, and with increased pressure increased heat was generated. Under these conditions the bar became intensely hot and red, and the wheel almost ceased to cut.

Complicated with these questions of heat is the subject of contact area and clearance. The ideal conditions of grinding are those in which wheel and work come in contact on a narrow line. A thin edge of saw steel will be

ground rapidly and effectively if pressed against the face of a wheel, while a large flat surface shows little product if pressed against the side. While this is partially due to the vastly greater pressure per square inch in the case of the thin edge, it is also due to the lower heat which results from proper clearance. In the case of the thin edge all débris of wheel and metal fly instantly away, each grain removing its quota of heat. In the case of two large flat surfaces rubbing together the débris is retained (with its included heat) and is bruised into the interstices of the wheel, interfering with its cut. For this reason it is a radical mistake to fit wheel and work in such way that large surfaces are in contact. Cone wheels exactly fitted to corresponding interior metal surfaces (axle-skeins, for instance) are a mistake. So would large, curved grinding blocks be if applied like brake-shoes to the curved face of a car wheel.

The tread of car wheels has long been ground in a practical way with an ordinary disc-shaped emery wheel, the curved exteriors merely touching on a narrow line and affording excellent clearance for wheel and metal débris. For this process, some years ago, was substituted a grinder, in which cup-shaped wheels were used. When the writer of this paper saw that machine in operation, a keg of grain emery stood close at hand, and the operator from time to time dropped some of it between the car wheel and the emery wheel. Questions and further examination brought out the fact that flecks of metal adhered periodically to the emery wheel, and that no proper work could be done until these were removed by the use of the loose grain emery. It was stated that the formation of a single fleck could be heard at the most distant corner of the shop, and this proved true. It was also stated that, when the rims or cutting edges of these wheels were pretty well worn down, such rims were removed entirely, and the wheels transformed into ordinary disc wheels. In this altered form, when the convex exterior of the grinding matter was used instead of its flat side, the wheels did good work and no metal adhered to them.

In the absence of verified data as to the relative cutting

capacity of small and large wheels, it is well to point out the manner in which circumference and mass modify the effects of frictional heat. The circumference of a 6-inch wheel is about 19 inches; that of a 36-inch wheel about 113 inches. A wheel 6 x 1 contains about 28 cubic inches; a wheel 36 x 4 about 4,000 cubic inches. The standard speed of a 6-inch wheel is 3,600 revolutions per minute; that of a 36-inch wheel 611 revolutions. If a bar $\frac{3}{4}$ x $\frac{1}{2}$ inch is ground on these wheels the heat problem will be different in each case. At the first moment, when bar and wheel come in contact at heavy pressure, intense heat will be developed. In the 6-inch wheel this spot (each and every point of contact) will be heated 3,600 times in a minute, while in the 36-inch wheel it will be heated only 611 times. Though both wheels travel at the same surface speed the circumference of the 36-inch wheel is so much greater that it has about six times greater ability to cool. The greater area of its surface causes greater radiation and loss of heat, while that which remains has about 4,000 cubic inches of matter to diffuse itself through, instead of the 28 inches allotted to the 6-inch wheel. If, therefore, frictional heat is an undesirable thing, the advantage of large wheels becomes evident.

There is *apparently* one clear deduction from these facts, and this is that water should be used to prevent the injurious effects of heat. Nothing can be more erroneous than this deduction, and nothing has done more to retard the proper development of grinding processes. The use of water on solid emery wheels is a survival of the old Sheffield methods, in which huge grindstones are run in a stream of water in which the workman straddles a board that presses his work against the stone in which the heaviest man is the best grinder.

The use of water has been urged indiscriminately as an excuse for an increased variety of grinding machines, and, in times past, as a method of using emery wheels too weak and poor to be used dry. It is not an uncommon thing to read, in commercial literature, that certain wheels can be used equally well wet or dry. In justice to the getters-up

of such vague assertions, it is assumed here that they are not intended to imply equal products by the wet and dry processes. It is to be feared, however, that the long-continued and oft-repeated assertion of this generality has created a false impression.

In opposition to any such view, it should be stated in the strongest way that water is a lubricant. Exact data on this subject seem to be almost entirely lacking, but the only ones known to the writer (and procured under his supervision) are now given. Seven different makes were tried under conditions identical except as to the fact that in one series the wheels were used dry and in the other series wet. Sixteen consecutive, intermittent cuts were made by each wheel in each series of trials, the speed being about 1 mile per minute, the pressure about 112 pounds per square inch and the material ground cast iron. The total product of five of these wheels under the dry process was $186\frac{13}{16}$ ounces, while under the wet it fell off to $24\frac{3}{16}$. Two (out of the seven) wheels gave a larger product under the wet process than under the dry, but this result confirms the facts previously adduced as to over-hard wheels and the lessened product due to metallic adhesion. In 32 minutes these two wheels ground off, under the dry process, $2\frac{3}{16}$ ounces and, under the wet process, $10\frac{2}{16}$. It seems evident that in this case the use of water lessened the metallic adhesion.

The fact is that water is only necessary to protect metal from the effects of heat. Where there is danger of warping in some article held while cold under the stress of undue tension, or where some desired temper is altered, water can be advantageously employed, but its indiscriminate use (on tools, for instance) encourages careless methods. The dry process carries on a steady educational work, the grinder acquiring increased delicacy of touch and greater knowledge as to the contraction, expansion, density, stress and temper of metals.

It is a too common assumption that tools cannot properly be sharpened on a dry wheel, yet experienced operators can produce any desired temper by the skillful use of the dry process. The tempering furnace has been (in at least one

instance) abandoned for a tempering wheel, and saws have been given an increased durability by the special hardness due to careful use of a dry wheel.

One final tabulation is now given to substantiate these statements. The advantages of intermittent pressure, as affecting the heat problem, are very evident, and the disadvantages of grinding with a flat surface have been pointed out. The facts that high speed is connected with a free cut, and that a free cut generates the least heat, are well understood. It will, therefore, be readily perceived that if a knife edge is ground on the flat surface of a wheel at half speed, under an unyielding screw feed, all the elements of temper destruction are present. Nevertheless, a 2-foot planer-knife, with bevel $\frac{1}{16}$ of an inch wide, has been successfully ground on an automatic knife-grinding machine with a dry wheel, under the disadvantageous conditions just stated. The record states that such grinding did not blue the knife, which remained cool enough to handle. If a machine can do this, what will not the sensitive and delicate hand of a skilled workman accomplish?

The art of grinding is still in its infancy. There is great need of long-continued, careful investigation, verified statistics and sound deductions before wheel-makers can learn what to claim and wheel-users know what to demand. At present the solid emery wheel is a greatly abused tool, and the emery wheel industry is in undeserved ill-repute.

The emery wheel will accomplish all that its warmest advocates claim if it is used with average care and skill under conditions perfectly reasonable and easily established.

APPENDIX.

SUNDRY ABSTRACTS.

Abstract No. 1 relates to tests made by T. Dunkin Paret, November 17, 1903, to January 29, 1904:

No. 1.

Metal ground, cast iron in bars, inches	¼ x ½
Approximate pressure in pounds per square inch	112

Quantity of emery wheels used	36
Classes " " " "	26
Number of 1-minute tests	244
Average number of revolutions per minute	2,220
" diameter of wheels in inches	9½
" metal removal per minute in ounces	2·678
Maximum " " " " " "	4·68
Minimum " " " " " "	1·
Average wheel loss per ounce of metal removal	·165

Abstract No. 2 relates to tests made by T. Dunkin Paret, February 5, 1904, with specially selected fast-cutting emery wheels:

No. 2.

Metal ground, champion tool steel in bars, inches	¼ x ½	¼ x ½
Approximate pressure in pounds per square inch	80	110
Quantity of emery wheels used	2	2
Classes " " " "	2	2
Number of 1-minute tests	8	8
Average number of revolutions per minute	2,212	2,257
" diameter of emery wheels in inches	$9\frac{0}{64}$	$9\frac{2}{64}$
" metal removal per minute in ounces	·63	3·05
Maximum " " " " " "	·93	4·31
Minimum " " " " " "	·31	·75
Average wheel loss per ounce of metal removal	·17	·36

Abstract No. 3 relates to tests made by T. Dunkin Paret, February 2 and 5, 1904, with specially selected fast-cutting emery wheels:

No. 3.

Metal ground, cast iron in bars, inches	¼ x ½	¼ x ½
Approximate pressure in pounds per square inch	80	110
Quantity of emery wheels used	3	3
Classes " " " "	3	3
Number of 1-minute tests	12	12
Average number of revolutions per minute	2,233	2,263
" diameter of emery wheels in inches	$10\frac{3}{64}$	$10\frac{2}{64}$
" metal removal per minute in ounces	3·09	5·38
Maximum " " " " " "	4·56	7·12
Minimum " " " " " "	2·00	4·18
Average wheel loss per ounce of metal removal	·094	·125

Abstract No. 4 relates to tests made by T. Dunkin Paret, December 8, 1903:

No. 4.

	Total Number of Minutes.	Total Metal Removal in Ounces.	Minute Average of Metal Removal in Ounces.	Total Loss of Wheel Material in Ounces.	Minute Average of Wheel Loss.	Size of Bar, Cast Iron.	Diameter of Wheel.	Pressure per Square Inch.	Revolutions per Minute.
1	4	12·50	3·12	16·18	4·04	¼ x ½	10 1/16	112	2280
2	4	13·25	1·31	15·62	3·90	"	10 3/16	"	2260
3	4	6·81	1·70	+1·25	—	"	10 3/16	"	2270
4	40 sec.*	—	—	—	—	"	10 3/16	"	2270
5	4	13·81	3·45	1·81	·45	"	10 3/16	"	2280

*Broke badly in 40 seconds.

No. 5a.

No.	Revolutions per minute when bursting occurred.	Nature of Binding Material.	Origin.	No.	Strength in kilos and decimals of same.	Nature of Binding Material.	Origin.
1	4,063	Vegetable	European	1	251·3	Vegetable	European, A.
2	3,967	"	"	2	238·8	"	" A.
3	3,770	Mineral	"	3	212·9	"	" A.
4	3,737	Not Stated	"	4	201·4	Unknown	" A.
5	3,727	Vegetable	"	5	198·6	Vegetable	" A.
6	3,647	Animal	Tanite	6	190·5	Animal	Tanite, A.
7	3,643	Vegetable	European	7	184·2	Vegetable	European, A.
8	3,493	"	"	8	182·7	Mineral	" A.
9	3,307	Mineral	"	9	155·4	"	" A.
10	3,237	"	"	10	153·0	"	" A.
11	3,177	Chemical	"	11	140·4	Vegetable	" A.
12	3,040	Vegetable	"	12	134·2	Mineral	" A.
13	2,953	Chemical	"	13	125·8	Chemical	" A.
14	2,940	Mineral	"	14	123·4	Mineral	" A.
15	2,840	Chemical	"	15	108·3	Chemical	" A.
16	2,807	Mineral	"	16	96·8	Unknown	Safety, B.
17	2,760	Not Stated	Safety	17	95·7	Chemical	Norton, A.
18	2,680	Chemical	Norton	18	88·2	"	European, A.
19	2,615	"	European	19	73·9	"	" C.

A. A set of three wheels.
B. One wheel.
C. A set of two wheels.

Wheels were called for in sets of three, each set to be of exactly the same binding material.

Abstracts Nos. 5a and 5b relate to preliminary report of Prof. M. Grübler, of the Technical High School, Dresden, Germany, concerning tests made by instruction of the Association of German Engineers. Report dated May, 1902:

No. 5b.

Number of wheels tested	54
" complete sets tested	17
" incomplete sets tested	2
Origin of wheels, European	47
" " American	7
Approximate size of wheels, in millimeters	500 x 50
" " " in inches	20 x 2
Ordinary standard working speed, revolutions per minute,	1,080
Maximum weight of one wheel, in kilos	39·95
Minimum " " "	20·01
Maximum circumferential velocity per second, in meters	110·44
Minimum " " " "	64·72
Maximum bursting point, in revolutions per minute	4,210
Minimum " " " "	2,520
Average " " " "	3,312
Maximum strength in kilos	251·3
Minimum " "	73·9
Average " "	159·1
Binding material of wheels, vegetable	18
" " " mineral	15
" " " chemical	14
" " " unknown	4
" " " animal	3

Abstract No. 6 relates to the tests mentioned in the "Report by Coleman Sellers, J. E. Denton and Alfred R. Wolff on the comparative value of fifteen varieties of Solid Emery Wheels." Report dated New York, September 9, 1891:

No. 6.

Number of wheels tested	78
" " burst	14
" trials attempted	193
" " completed	136
Average metal removed per minute, in ounces	2·108
" " " " " at 112 lbs. per sq. in.	1·409
" " " " " 266⅔ " " "	5·130
" loss of wheel material per minute (A)	·590
" initial cut per minute	1·955

Average final cut per minute	1·264
" maximum " "	5·662
" minimum " "	·118

In this computation the loss due to burst wheels is not considered, only the frictional wear being taken into account.

These tests were made upon bars of cast iron, $\frac{3}{4} \times \frac{1}{2}$ inch.

TABLE A.

Half-hour tests on brass, cast iron, wrought iron and hardened saw steel, with solid emery wheel, file, and hammer and cold chisel.

Weight of metal removed by	Brass.		Cast Iron.		Wrought Iron.		Saw Steel.	
	lbs.	*ozs.*	*lbs.*	*ozs.*	*lbs.*	*ozs.*	*lbs.*	*ozs.*
Emery wheel	17	0	7	12	2	8	3	7
File	0	8	0	5¾	0	2¾	0	1
Hammer and cold chisel	1	4½	2	5½	0	10½	0	1½

In obtaining the results tabulated above the same emery wheel was used on all the metals by the same man.

TABLE B.

Cost per pound of removing or wearing away metals, as based upon Table A.

	Brass.	Cast Iron.	Wrought Iron.	Saw Steel.
	cents.	*cents.*	*cents.*	*cents.*
Emery wheel	1·8	5·8	21·2	28·9
File	25·8	35·9	75·	206·4
Hammer and cold chisel	10·1	5·3	19·6	137·6

The cost table given above was arrived at as explained here. A uniform rate of $2.50 per day of ten hours was fixed for grinder, filer and chipper, and 3 cents per ounce was fixed as the net cost of an emery wheel. A solid wheel 14 inches in diameter and 2 inches thick (the size adopted in all the trials), weighs about 30 pounds, and is priced in some lists at $19.70. A discount of 33⅓ per cent. makes the net cost $13.13, or 2⅜ cents per ounce.

TABLE C.

Half-hour tests on brass, cast iron, wrought iron and hardened saw steel, with solid emery wheel and file.

	Brass.		Cast Iron.		Wrought Iron.		Saw Steel.	
	lbs.	*ozs.*	*lbs.*	*ozs.*	*lbs.*	*ozs.*	*lbs.*	*ozs.*
Weight of metal removed in one-half hour's grinding . .	17	0	7	12	2	8	3	7
Weight of metal removed in one-half hour by file	0	8	0	5¾	0	2¾	0	1
Weight of emery wheel removed in one-half hour's grinding	0	6½	0	11	0	13½	1	13

AUSTRALIAN OPALS.

The finest opals formerly came from Hungary, Mexico and Honduras, where they occur in igneous rocks. Australia is now the chief source of production, although the rich opal fields of White Cliffs, New South Wales, were only discovered by a mere accident in 1889. In 1902 the opals found in New South Wales were valued at $700,000 in all.

CYANIDE OF CACODYL.

Prussic acid has been considered to be the most deadly poison extant. Mr. Lascelles Scott, of Little Ilford, England, however, has now discovered a far more deadly poison—the substance scientifically known as di-methylarsine cyanide, or more familiarly as cyanide of cacodyl. Three grains of this substance diffused in a room full of people would kill all present, so powerful is it. So deadly is this poison that it is highly dangerous to handle it. It is a white powder melting at 33° and boiling at 140°. When exposed to the air it emits a slight vapor, to inhale which is death. Mr. Lascelles Scott has experienced the deadly nature of this poison, for while he was assisting Sir B. W. Richardson in the compilation of his work, "On the Causes of the Coagulation of the Blood," he tried its effect upon animals. One millionth part of cyanide of cacodyl in the atmosphere of an air-tight cage killed a dog almost instantaneously, and then its power was by no means exhausted, for a second, third and fourth dog placed in the same cage, instantaneously died from the effect of that single infinitesimal dose. Although so little of the properties of this poison are known, it was first made many years ago. Cadet, the famous French chemist, by combining acetate of potassium with white arsenic, produced a fuming liquid which, although he did not know it, was oxide of cacodyl. The German chemist Bunsen combined this with cyanogen, a radical of prussic acid, and made cyanide of cacodyl, the formula of which is As_2Me_4Cy.—*Scientific American.*

Mechanical and Engineering Section.

Stated Meeting, held Thursday, March 24, 1904.

The Execution of Architectural Design.

By John McArthur Harris, M.A.,
Member of the American Institute of Architects.

(*Concluded from p. 74.*)

Some years ago a contractor overthrew an adjoining building. He was digging the cellar for the building he was to erect, and promptly failed. It was rumored that he had been paid no money for work up to that time, and that he had given no bond. The loss to the adjoining property was greater than the amount of work done by the contractor, so that the owner, without having spent a cent was in a position to lose thousands of dollars. I do not know what was the result of the catastrophe—that is, who bore the loss; but I do know that the danger of loss on the part of the owner could have been avoided if the bond had been promptly executed.

Contractors are usually required to keep buildings in course of erection insured from loss by fire and to assign the policies to the owner as his interest may appear. In case of a fire, contractor and bondsman together might not be able to bear the loss. Hence the identification with them for this emergency of the Fire Insurance Company.

Another security that is afforded the owner arises from the fact that it is customary to pay the contractor only a portion of the value of the work done from time to time until the work is completed. These payments are made on what is known as architect's certificates, which are simply vouchers that the contractor is entitled to a certain amount of money. This amount is usually arrived at by estimating the value of the work at stated intervals, and retaining a certain percentage, as stated above. The importance of the certificates arises from the fact that they are the basis of

payment recognized by the contract. And if the owner does not honor them, or pays without waiting for them to be issued, he lays himself open to loss in more ways than one. He may lose his contractor or his bondsmen, or he may have mechanics' liens filed on his building—provisions of the contract notwithstanding, because he has violated that contract.

The mechanics' lien is one of the strange things of the building business, and I think the law-makers have recognized the anomaly, because they have provided protection against it.

If the contractor fails to pay any of his employees, that employee can file a lien or claim on the building, and the owner must satisfy it, even though he has already paid the contractor for this very work.

To avoid this possible double payment on the part of the owner, the law of Pennsylvania provides:

WAIVER OF RIGHT TO FILE A CLAIM.

"SECTION 15. The right to file a claim may be waived by agreement between the claimant and the party with whom he contracts, or by any conduct which operates to equitably estop the claimant. If the legal effect of the contract between the owner and the contractor is that no claim shall be filed by anyone, such provision shall be binding; but the only admissible evidence thereof as against a sub-contractor shall be proof of actual notice thereof to him before any labor or materials furnished by him, or proof that a duly written and signed contract to that effect has been filed in the office of the prothonotary of the Court of Common Pleas of the county or counties where the structure or other improvement is situate prior to the commencement of the work upon the ground, or within ten days after the execution of the principal contract, or not less than ten days prior to the contract with the claimant. The only admissible evidence that such a provision has, notwithstanding its filing, been waived in favor of the claimant, shall be a written agreement to that effect signed by all those who, under the contract, are interested antagonistically to the

claimant's allegation. The giving of credit or the receiving of collateral security shall not operate to waive the right to file a claim, but shall delay voluntary proceedings thereon by the claimant until the time of credit shall have expired. A release signed by the claimant shall not operate as a waiver of the right to file a claim for labor or materials subsequently furnished unless it shall appear thereby that such was the express intent of the party signing the same; but such release shall be so construed as to fully carry out that intent."

The idea of this law is that persons who would have the right to lien may find out when payments are to be made and protect themselves at that time. Now if the owner makes his payments irregularly he takes away from the mechanic this protection and so gives him a right to protect himself by putting a lien on the building which the contract stipulates against. This is only one of the many illustrations that constantly arise of the necessity of:

(1) Having the contract fully expressed.

(2) Having it literally carried out.

It is the custom, before making a final payment and closing a contract, to have the contractor furnish a release of liens, which is simply a statement signed by all who would have the right to lien that they waive this right. This release will be required until the Supreme Court passes fully on the Act of June 4, 1901, quoted above, when it will become unnecessary.

The last instrument we have to deal with to-night is the guarantees. By this I mean certain guarantees that require time for their fulfilment, and unless satisfied in some way would keep open the contract longer than may be expedient. It sometimes happens that under a contract the contractor guarantees the working of apparatus furnished by a subcontractor—and at the completion of the rest of his obligations desires to terminate the responsibility he is under. This is often done by forming new contracts directly between the interested parties, and if the security is good the practice is not objectionable.

We have now reviewed together this somewhat extensive

field. I have named the parties who are interested in the carrying out of the design, and I have described in a very limited way the instruments that held them together, but we have still one matter to consider.

The owner, the architect and the contractor, these three are united in common purpose by a contract; but before this can take place there must be *selection*, first, of the architect; second, of the contractor.

How is this to be done?

The architects of the United States have a recognized organization which declared in its standard of practice:

"That the best results were to be obtained by an owner selecting his architect rather than by competition."

This practice is unobjectionable because the architect's charges are easily reckoned and readily compared so that he cannot overcharge.

The selection of a contractor is a more difficult problem, and many different methods are in use to determine the proper man to be selected.

Before I state some of these I would like to go over the condition of the contracting business as it exists to-day.

I spoke above of the change that has come over this business with reference to the manner of bonding the contractor. This is due, as I stated, to no ethical cause, but largely to the enormous financial load carried by the contractor.

By the introduction of the Bonding Company into the position of a partner, as it were, the contractor relieves the owner of anxiety with reference to the contractor's financial responsibility, but the practice has done more than this. It has brought into the competition many men who are not sound, but who hide behind the bonding companies when their standing is inquired into. The statement "I will give bond" is supposed to cover all questions of this nature.

Now, if the financial load has increased enormously, the practical load has fully kept pace with it. In the days of my grandfather the contractor could and often did know about all that went into the building. The few gas, water and other pipes, the furnaces, bricks, stone and mortar that

went into the building were comparatively easily carried in mind, and their installation followed.

Our builders cannot follow the huge contracts of to-day in the same manner. They sublet their work, of course, and they also sublet their obligations.

I have seen contracts between general and sub-contractors made so that everything the architect could ask the general contractor to do, the sub-contractor bound himself to execute. Reverse this and you have the rule that what the architect does not demand from the general contractor the latter will not demand from the sub-contractor. It would be a great thing for the building business if such contracts as this could be prevented. I know one large company in this city that has refused to sign an agreement of this nature, and that will make only independent contracts with general contractors.

I know of another company that overlooked the question of the financial responsibility of the general contractors with whom they made contracts, and depended almost entirely on liens to collect their money. This was an extreme case, and I use it as an illustration only to show how many forces are at work to relieve the general contractor of responsibility.

One of our leading contractors told me within six months that business was no longer conducted at the building but at the office.

I am not scolding. General contractors find as much fault as I do with the present system. I am simply stating conditions. And the condition I want to emphasize is this: That while the principal actor in the second period of design is the contractor, that is the general contractor, the standard of the work is no longer measured by the practical and financial ability of the contractor, but by that of his sub-contractors.

The usual method of selecting the contractor is to invite a limited number of contractors to bid, and to give the work to the lowest bidder.

The governmental way is to invite everybody that is in that particular line to bid, and to give the work to the lowest and best bidder.

It is customary in both methods to make a contractor submit a list of his sub-bidders, but the difficulties here are twofold. The contractor cannot be expected to change these sub-contractors for better ones without raising his price. He has accepted a poor sub-contractor to keep the price down and win the competition, and it is difficult to get the owner, who relies on architect and contractor to see that he gets good work, to pay more for good sub-contractors. It is dangerous, too, for an architect to dictate overmuch in the selection of sub-contractors, as it lessens the general contractor's moral responsibility.

Two other methods are:

(1) For the owner to pay all the bills and a percentage to the contractor. This is known as day's work, and is the poorest method of all. The contractor does not have to watch his force account, and the chances are he does not watch the job at all. He knows that the more the work costs the owner, the more the contractor will make. It reminds one of the old story of the Yankee and the Indian and the turkey.

(2) For the sub-contractors to be selected by competition from a selected list and the contract to be made for a lump sum, which shall include a fee for the general contractor, who shall be selected for practical fitness.

This way I like the best, provided a competent general contractor is selected, and provided the sub-contractors are not asked by the general contractor to take less than their original bids.

From the reports of sub-contractors, I judge it is a common practice for contractors to use sub-bids in making their own price, and to shave them when making their contracts with the sub-contractors. This concession on the part of the sub-contractor has to be met by the general contractor, and this vitiates his superintendence.

You have heard now the methods in vogue and you have listened to some of their limitations. I have not, in much discussion with architects and more with contractors, had any perfectly satisfactory method suggested.

Recently there have been signs of a new departure, new

only in the sense of its growing favor. This is, for the architect to make the contracts in place of the general contractor. This method has many objectionable features, but it has the great advantage that it enables the architect to deal directly with the men who are doing the work.

The owner finances the work by paying for the bond and by advancing money as the contract progresses. He superintends the work through his architect, who takes the moral responsibility for its success. The question arises: Are we to go forward in this direction towards the elimination of the general contractor from building contracts? It would be a brave man who would now predict it.

The great objection to the architect as a contractor is a moral one. It has always been considered better practice to have work superintended by a disinterested party, and it can be readily understood that it is better to have specifications drawn by parties who are disinterested, so that it may not be for the advantage of the profession to include general contracting.

The new Land Title Building, erected without a general contractor, may be only a monument, not a mile-stone, but the problem is one that must be faced and some day settled. I wish to excite your interest in it, and among yourselves and friends your discussion of it, so that as it becomes more urgent it may have had the study of earnest and able minds, for only by such study can its solution be along lines that will advance The Execution of Architectural Design.

TIN DEPOSITS OF THE YORK REGION, ALASKA.

Julius Cæsar's invasion of Britain marked many important beginnings in the history of the civilized world. It is said that one result of that epoch-making event was the revelation to the Roman world of tin mines in the hills of Cornwall. The popularity of that useful white metal began with its earliest importation to Rome, and has continued down to the present day; but the sources of the world's supply of tin have unfortunately not grown proportionately with our knowledge of the world. The mines of Cornwall are still productive, and like those of Bolivia and Saxony, furnish tin from vein deposits in the bed rock. But the greater part of the world's supply of tin is now obtained from alluvial deposits. Over three-quarters of it comes from alluvial deposits in the Malay Peninsula, otherwise known as the Straits

Settlements, and the islands of Banca and Billiton, off the north coast of Sumatra. Alluvial deposits in Australia also contribute to the total output. The world's production of tin in 1903 amounted to 92,536 long tons, of which the Straits furnished 54,797 tons, Banca 15,070 tons, Billiton 3,653 tons, Bolivia 9,500 tons, Cornwall 4,150 tons, and other countries the balance. Only 30 tons of this total amount were mined in the United States, and not more than 200 tons of metallic tin have ever been produced from ore mined in this country, although small amounts of tin have been found in no less than seventeen States and Territories. These facts lend unusual interest to the discovery of tin in our Alaskan possessions. A report entitled "The Tin Deposits of the York Region, Alaska," by Mr. Arthur J. Collier, has been recently published as Bulletin No. 229 by the United States Geological Survey in response to the demand for reliable information regarding the occurrences of tin noted in Alaska.

Placer tin was discovered in 1900 in the York region of Seward Peninsula, which is the land mass that projects from the west coast of Alaska to within 60 miles of Asia. Mr. Alfred H. Brooks, of the Survey, found in the placers of Anikovik River and Buhner Creek, one of its tributaries, some concentrates which proved to contain stream tin. Since that time an effort has been made to determine the extent and distribution of the stream tin and locate its source in bed rock. Though the occurrence of tin-bearing lodes had been previously reported, the first authentic discovery of this kind was made by Mr. Collier during the summer of 1903. Accompanied by Mr. F. L. Hess as field assistant, he visited Teller late in July, and there met a number of prospectors who had been searching for tin in the York region and who were anxious to have their specimens examined, since they were unable to identify tin ore. Among these specimens only one piece of tin ore was found, but it had been obtained in a new locality, and consisted of cassiterite crystals still in the matrix. During the following week Messrs. Collier and Hess visited Lost River, Buck Creek, and Cape Mountain, and located the tin deposits at those places. The results of their investigations are embodied in this bulletin, together with information derived from a study of specimens of tin ores and associated minerals recently brought from the York region by outside parties.

The geologic results of investigations made by members of the Survey will be published in detail at a later date, but brief descriptions of the general and economic geology of the region are included in this bulletin. Some valuable data concerning the means of transportation in this district and the fuel supply are given. The physical characteristics of tin ore and its associated minerals—tourmaline, garnet, rutile, wolframite, epidote, magnetite, fluorite and quartz—are described, and methods of assaying tin ore are discussed, among them a method elaborated by Mr. Eugene C. Sullivan, chemist of the Survey, by means of which minute traces of tin can be detected. A brief description of the better known tin deposits of the world is included in the bulletin in the hope that it may be of value to the prospector. The essential purpose of the bulletin is, indeed, to present such facts in regard to the occurrences and value of the metal as may be of assistance to those who are interested in the development of the field. The bulletin is printed for gratuitous distribution, and may be obtained on application to the Director of the United States Geological Survey, Washington, D. C.

ELECTRICAL SECTION.

Stated Meeting held Thursday, January 17, 1904.

The Storage Battery as Applied to Electric Railways.

By W. E. Winship.

Within the last few years there has been a decided change in the attitude generally taken as to the advantages and advisability of storage-battery installations. This is partly due to a better knowledge of the life which may reasonably be expected, and, to a minor extent, to improvements in construction and plates.

Storage batteries have shown their utility and economy especially in railway work, where current fluctuations are usually extreme.

Where the system, supplied from a single station, is large, and relatively small cars are operated, the instantaneous fluctuations will be a small percentage of the total load, and there would be no economy gained in removing them. The load in this case will very nearly follow the service supplied; *i. e.*, be steady and proportional to the number of cars, and the only effectual use of a storage-battery plant, outside the large element of reliability of operation secured by it, would be in regulating the load-factor on the generating units in service. There would probably be, even in this case, a considerable economy resulting in operating the generating units and boilers at their most efficient load. This fact and their importance as a reliability factor might determine their installation under the above conditions.

When large cars are operated, perhaps even in trains, and high accelerations are demanded, as in interurban work, the conditions are entirely different. The fluctuations are then enormous, frequently much in excess of 100 per cent. over the average load, and we very often find stations operating on a 50 per cent. load-factor in order that the maximum demand may be within the overload capacity of the generators.

As is well known, the efficiency of a steam engine is greatly reduced, and that of a generator also, to a smaller extent, when the average is much less than their rated load. With steam turbines this is true to a somewhat less degree, but there is still a great variation of steam consumption. The net efficiency of the engine-generator combination is the product of the efficiencies of the two, and suffers, therefore, more greatly than either singly. By using a storage battery, either with or without a booster, to absorb these fluctuations, it becomes possible to raise the load-factor by shutting down one or more engines and boilers, with a consequent decrease in coal consumption, reducing also such items as labor, oil, waste and repairs, thereby effecting a great economy. It is possible then to operate with less apparatus, and usually some saving may be made in initial power-house outlay, since an equivalent battery plant would cost somewhat less than the engines, boilers and generators it displaces.

As with all machines and contrivances, the efficiency of a storage battery plant is not perfect. On certain classes of work (viz., short cycles of charge and discharge) it is remarkably high. If the fluctuations are within the hour-rate of discharge of the battery, and are of short duration, it is very nearly 90 per cent. Tests published by Highfield,* covering a year's actual operation of a battery plant on such work, showed a net Watt-hour efficiency of 84 per cent.

On complete charge and discharge cycles, it is decidedly less, 87 per cent. with the ordinary stationary types of batteries being about as high as can be obtained, while under practical operating conditions it is less than this, running from 70 per cent. to 80 per cent. according to the class of work the battery is called on to do. In spite of this fairly low efficiency the use of such a "peak" battery may result in a very considerable saving. Most especially is this true when the source of supply is a water-power of limited capacity, and, as already pointed out, as an emergency it is invaluable.

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* *Journal I. E. E.*, Vol. XXX, p. 1070. See also Hopkinson, *London Electrician*, Vol. XLVIII, p. 211.

The capacity of a storage battery is given in ampere hours, and varies with the rate of discharge. Taking the capacity as 100 per cent. at the 8-hour rate, the capacities at the 5-, 3- and 1-hour rates are 87½ per cent., 75 per cent. and 50 per cent., respectively. The capacity of a storage battery is arbitrary to a certain extent; that is, a battery could be discharged for a longer time than would correspond to these figures. If, however, the discharge is continued beyond these values, the voltage drops too rapidly for good efficiency. It should be noticed that by saying the capacity at the 1-hour rate is 50 per cent. of that at the 8-hour rate, we do not imply that twice as many ampere hours must be put in as are taken out, for this is not the case. The ampere-hour efficiency of storage batteries is very good, being 95 per cent. to 98 per cent.

To take care of the fluctuations on a power or sub-station, there are several ways of operating storage batteries. Necessarily, the voltage of a battery rises on charge and falls on discharge. If the generators have a falling characteristic, that is, the voltage drops with increasing load, and the maximum permissible amount of this drop is considerable, say 5 per cent. to 10 per cent., then a battery may be simply "floated" across the bus-bars, and will charge when the external load is light and discharge when it is heavy. The extent of the load equalization under these circumstances will depend on the sharpness of decrease in voltage, and the duration and magnitude of the fluctuations with reference to the size of the battery. Roughly, it may be stated that with a 5 per cent. to 7 per cent. variation of voltage above and below the normal and with current variations equal to the 1-hour rating of the battery, lasting for several seconds, the generator load variation will be constant to within 5 per cent. It is possible to adjust the combination of battery and generators for different load factors in either of two ways: first by cutting in or out a certain number of cells or by raising or lowering the average voltage of the station.

In many instances, however, it is essential that the voltage be maintained fairly uniform. Under these circumstances,

in order to have the battery charge and discharge, the difference in voltage between the battery and the system must be made up automatically in some way. It is usual to employ a differential booster for this purpose. A brief description of such boosters may not be out of place. There are two booster systems which have come into general use in America, both of which are usually motor-driven.

In the one form the booster generator field consists of a shunt winding, to which is opposed a series winding, a portion of this latter carrying the generator load, while through the remainder is passed the external load. The shunt winding is so determined that with no external load the voltage of the booster generator will be equal to the maximum difference of voltage between the battery and generators. The series winding is so determined that with both generator and external load equal to the average, the resultant field and consequently the booster voltage is zero. One of the objections to this arrangement is that the resultant field is small in comparison with either component, and in consequence there is a serious amount of energy dissipated in the field magnets. The field energy has practically the same value independent of the battery load, so that the amount of this loss is of considerable magnitude. The self-induction of these abnormally heavy windings is very great and the pole legs of the field magnets necessarily long to accommodate them; these two facts condition a relatively slow response of the booster to variations of the load.

In the second form, the booster-field regulation is obtained through the use of a small auxiliary generator, whose field carries the generator load. This machine is so determined that with the generator load at its normal value the voltage is equal to that of the system. The booster-field circuit includes the armature of this auxiliary machine and is connected across the generator bus-bars. The result is that, with the average current in the auxiliary machine field, the voltage impressed on the booster field, and consequently the booster voltage, is zero. If the generator load increases by a small amount, the voltage of the auxiliary machine increases by a corresponding amount, and there is

a resultant voltage impressed on the booster field, thus causing the booster to assist the battery to discharge. This machine may be so calculated that the generator load may be kept constant to within any predetermined limit. It has the advantage that there is no energy in the booster field when it is not required, and also that the regulation is dependent on the load which is to be regulated.

The length of the booster field magnetic circuit is normal, and the field windings are composed of a relatively small number of turns (for a booster on railway work usually wound for 50 volts maximum); as a result, the response of the booster is almost instantaneous.

The determination of the size of a battery installation will depend on two elements: the maximum discharge rate which it is required to deliver, and the required storage capacity. When a battery is simply to act as a load equalizer, independently of its storage capacity pure and simple, then it is obvious that the battery should be chosen on the score of cost as small as is consistent with efficiency and life. For this purpose that type of battery which is calculated to withstand a maximum discharge rate with the least amount of deterioration and least drop in voltage should be chosen. These properties attach to plates having a great surface exposed to the electrolyte in the cells.

The combination of equalization of both instantaneous fluctuations and peaks of the average load is especially useful with water powers of limited capacity, as it is possible then to obtain the maximum output capacity of the plant. Another very prominent advantage, especially in operating on comparatively low heads, is that the difficulties of governing are largely obviated. This is of extreme importance in alternating current installations.

An example of such an installation, at Easton, Pa., may be quoted. The power plant consists of two 2-phase alternators, driven by water-wheels, located in a station about 1½ miles distant from the main power-house. In this latter are steam-driven auxiliaries. A mixed railway and light service is furnished. Before the installation of this battery an 800-horse-power steam unit was in constant use to rein-

force two A. C. motor generator sets, driven from the water-power, in order to care for the instantaneous peaks of the railway load. Since the installation of the battery, the water-power carries both the railway and lighting load. During the day the battery equalizes the railway load, receiving also a slight net charge; when the lighting load comes on, the battery furnishes a net discharge to cover the difference between the water-power capacity and the total load on the plant. From 12 to 4 A.M., when the load is extremely light, the battery is re-charged. They are able then to carry their load under normal conditions without the use of steam, excepting for certain auxiliary service, and are able to shut down an 800-horse-power unit, and in addition to this advantage, by the removal of the railway load fluctuations, their lighting service is extremely satisfactory.

The preceding has reference to installations in central or sub-stations. Under certain conditions, it is advantageous to install batteries at points distant from generating stations. Such installations are of two types—"floating," or fed from a boosted feeder, and are termed line batteries. In electric railway work such batteries would be located at some distance from the generating station to maintain the line voltage.

In the case of a battery at the end of a boosted feeder, it is usual to transmit the average current, allowing the battery to absorb or give up the difference between the instantaneous and average currents. Such an installation may have a very fair efficiency, and will show a decided advantage over a high-tension transmission and sub-station scheme if the frequency of the car service does not justify the first cost and attendance required by the latter. The instances where these conditions hold are extremely numerous in interurban work. In many cases, however, a battery simply placed across the line will serve every purpose of the above, and will show several advantages over it.

It is obvious that the voltage at different points could be maintained by copper, but the amount of copper would often be excessive. It is of great importance to maintain the voltage on the line at as high a value as is possible, for

several reasons. It is the charactertistic of series motors, such as are used in railway work, to take a definite current on definite grades outside of periods of acceleration and independent of the speed of a car. The speed will vary very approximately as the applied voltage; it is obvious, then, that to maintain a given schedule less cars will be required with high than with low voltage. Again, with cars on a grade or accelerating, the periods of taking excessive currents are of shorter duration with the higher voltage. The heating of the motors will depend largely on the time that these heavy currents are demanded, and as a result the motors will deteriorate and burn out very rapidly if the line voltage is too low. This item of motor repairs is a very serious one in electric railway operation. Again, the loss in transmission with low voltage is excessive. Taking into account the schedule speed and the transmission losses, the energy consumption will be approximately inversely as the squares of the applied voltages.

If the amount of copper is sufficient to furnish the average demands of the cars with a relatively small drop, when the cars are accelerating or mounting grades distant from the power-house, especially when the service is supplied by only a few cars, the drop becomes excessive, and is felt all over the line. If a battery be installed at a point about three-fourths of the distance from the power-house (which point would be modified somewhat by the location of grades), whose voltage is equal to the voltage which would exist at this point if all the cars were taking the average current, then it would charge on light loads and discharge when the load becomes heavy. This results in a very considerable equalization of load on the power-house and in the maintenance of the voltage at the battery location at approximately a constant value, varying only 5 per cent. to 7 per cent. above and below the average. The battery will then neither experience a net charge nor discharge. Such batteries have been installed by putting in the number of cells corresponding to the average voltage before the erection of the battery. It is easily seen that the two values, voltage at this point with the cars taking the average current, and

the average voltage, may be quite different, as the battery will modify the latter quite considerably.

An objection sometimes brought against such an installation is that it has no flexibility. It is, of course, absolutely determined by the feeder scheme and the service on the line. If the latter is increased, the battery will experience a net discharge. But this may be taken care of as follows: A certain number of cells may be cut out of service, corresponding to the increased drop; or if the schedule varies with the time of day, the battery may be installed so that it receives a net charge during the lighter service and furnishes a net discharge when the greater number of cars are run, or the voltage of the power-house may be correspondingly varied. Sometimes the conditions would be met by a combination of these methods.

A small installation, at Berlin, N. H., will illustrate what may be accomplished in this way. The road runs from Gorham to Berlin Mills, and is approximately 8½ miles long. The power-house is ·75 miles distant from the Gorham end of the line; from Gorham to Berlin there are numerous 3 to 5 per cent. grades, with one short, heavy grade of about 12 per cent. near Berlin; toward Berlin Mills there are several 8 per cent. grades. The track is 60-pound rail; bonding in poor condition. The line consists of one No. 00 trolley, with a 400,000 C. M. feeder to within 1 mile of the end; from Gorham to the power-house there is a 400,000 C. M. copper return. A battery was installed in the car-barn 6·5 miles distant from Gorham, consisting of 230 cells, having a capacity of 280 amperes for 1 hour. Ordinarily two 16-ton cars are operated under 40-minute headway. If extra cars are run for a short time, no change is made in the battery. If, however, it is desired to operate a 20-minute schedule over 8 or 9 hours, thirty of these cells are cut out and the battery furnishes a net discharge of about 40 amperes. Before the battery was installed, it was impossible to operate more than the two regular cars. They are now able to operate four cars for 8 to 10 hours, and at times six cars are run.

What promises to be an exceedingly useful application

of floating batteries on interurban roads operating sub-stations at not too infrequent intervals is the installation of batteries in such sub-stations ordinarily to accomplish load equalization; in case of a breakdown of the sub-station of short duration, the battery would be placed directly across the line and allowed to discharge. If the breakdown is of long duration, a certain number of cells could be cut out and the battery "floated" between the two stations on either side to maintain the line voltage indefinitely at a value sufficient for continuous operation.

CHEMICAL ANALYSIS OF ROCKS.

A bulletin (No. 228) entitled "Analysis of Rocks from the Laboratory of the United States Geological Survey, 1880 to 1903," has been prepared under the direction of Mr. F. W. Clarke, the Survey's chief chemist, and is now ready for gratuitous distribution. During the four years that have elapsed since the last edition (Bulletin No. 168) was printed, over 1,000 analyses have been made, of which nearly 300 are included in this bulletin. In this edition the names are given which the rocks would bear in the classification proposed in 1903 by Messrs. Cross, Iddings, Pirsson and Washington in Professional Paper No. 14.

Over 5,300 analyses have been made in the chemical laboratory at Washington. These represent analyses of rocks, minerals, ores, waters, sediments, coals, metals and so on through all the range of substances with which geology has to do. A fair amount of research work has also been done upon mineralogical and analytical problems.

On account of the activity of the petrographers, the dominant feature of the laboratory work has been the analysis of rocks. These have been studied in great numbers and in the most thorough way. The results have appeared in widely scattered publications—in official reports, monographs, bulletins and American and foreign journals. The object of the present bulletin is to collect this valuable material, together with such bibliographic and petrographic data as seem necessary to identify the specimens and to facilitate chemical discussion.

Mr. Clarke has also given in this bulletin a new computation of the average composition of rocks, which agrees closely with his former estimates, but is founded upon more extensive data.

THE SIMPLON TUNNEL.

The Simplon Tunnel, when completed, says *Engineering Record*, will have a length of about 12·3 miles, and the heading from the Swiss side has been advanced 5 miles. In order to secure an adequate supply of air to the men working at the face, two parallel tunnels about 50 feet apart had to be

driven, the ultimate intention being to have one for the "up" and the other for the "down" traffic, but for the present, one bore will easily carry it, so that only one (No. 1) tunnel is now being completed. These two parallel tunnels are connected by cross-passages every 200 meters, though, as the heading advances, only the nearest cross-cut to the face is kept open. In No. 2 tunnel, that is, the tunnel not at present being completed, all the water pressure and air pipes are situated; it also carries the water flowing from the face of both tunnels. In advancing the heading, No. 1 tunnel is kept ahead of No. 2, so there is always a dead end beyond the nearest cross-cut to be ventilated. This ventilation is secured by laying a 14-inch pipe from the cross-cut air-current to the face, and using a high-pressure water injector, directed into the ventilation pipe, to force or induce air right into the face. The tunnel headings have an area of about 8 square meters, that is, about 7·5 x 10·5 feet, and at the time of my visit the rock through which they were advancing was *antigoro* gneiss. This rock, though very hard in places, is much split up and breaks easily; so much so, that in the face ten holes suffice for a round. A two-hole cut is sufficient, and the remaining holes are arranged symmetrically around the cut holes. Each hole is charged with 2 kilogrammes, or 4·48 pounds, of blasting gelatine, which is practically the same in composition as the explosives in use on the Rand. The actual work of drilling is performed by a set of three Brandt hydraulic drills, mounted on a horizontal hydraulic rack bar 12 inches in diameter, which is carried at the end of a pivoted lever, mounted on a four-wheeled lorry. By this arrangement the complete fixing, drills and rack bar can be run into position, the rack bar set at any convenient height across the tunnel and parallel to the face, and the latter firmly fixed in place, after attaching the valve of the rack bar to the pressure pipe and placing wood blocks at each end of the bar, by simply opening a valve.

ABSORPTION OF RADIUM EMANATIONS BY WATER AND PETROLEUM.

In a paper published in No. 8 of the *Physikalische Zeitschrift* (April 15, 1904), Prof. F. Himstedt arrives at the conclusion that radio-active bodies giving off a gaseous emanation are widely diffused throughout the earth. These emanations are absorbed by water or by petroleum; and after having been conveyed along with the latter to the surface of the earth, will diffuse into the air. Because of the many analogies noted between these emanations and radium emanations, the author thinks it possible that both are identical. In this case the ores of uranium from which radium emanations are derived would either be widely diffused, or else there would be some further matters possessing, though to a lesser degree, the property of giving off emanations. Considering that the absorption coefficient of water as well as of petroleum with respect to this emanation is found to decrease for increasing temperatures, while hot fountains on the other hand show an especially high activity, the hypothesis is suggested that the amount of radio-active material is increasing for augmenting depths, and, according to Curie's observation as to the continual heat evolution from radium, the radio-active components of the earth should possibly have to be allowed for in accounting for the temperature of the earth.

Ferrell's Apparatus and Process for Fireproofing Wood.

[*Being the Report of the Committee on Science and the Arts on the invention of Joseph L. Ferrell.*
Sub-Committee: Samuel P. Sadtler, Chairman; William McDevitt, Richard L. Humphrey, A. Raymond Raff.]

[No. 2261.]

The Franklin Institute, acting through its Committee on Science and the Arts, investigating the process of fireproofing wood, devised by Joseph L. Ferrell, of Philadelphia, reports as follows:

The limited time which the members of your committee could devote to this work prevented them from making as exhaustive an investigation as they desired. They have, however, considered those features which they deemed most essential.

The term "fireproof wood" is misleading and a misnomer. No process thus far known can render wood "fireproof;" the best that is attainable is to so treat wood as to make it "fire-deterrent" or "fire-resistant." There is nothing new or original in this fact. The British patent records on the subject date from 1625; the United States patent records from 1790, while the Greeks and the Romans considerably antedate these in the use of alum as a fireproofing medium. Since then many substances have been proposed and employed to render wood "fire-resistant,"—among which may be mentioned silicate of soda, tungstate of soda, alum in various forms, sulphate of ammonia, borax and salt.

None of these, however, fills the requirements of an ideal fireproofing substance, which may be summarized as follows:

(1) To render wood "fire-resistant" in the highest degree.

(2) To have no deleterious effect on the wood, but, on the contrary, serve as a preservative.

(3) To have no injurious effect on the strength of the wood.

(4) To have no hydroscopic qualities.

(5) To produce no efflorescence.

(6) To preserve the natural color of the wood.

(7) To have no injurious effect on varnish or paint applied to its surface.

(8) To be non-volatile under the action of heat.

(9) To exert no corrosive or rusting action on metallic substances.

Having obtained such a substance it is necessary to devise some means by which it can be successfully applied.

In the investigation of the Ferrell process, the committee for convenience has considered (1) the mechanical features; (2) the chemicals employed, and (3) efficiency of the process.

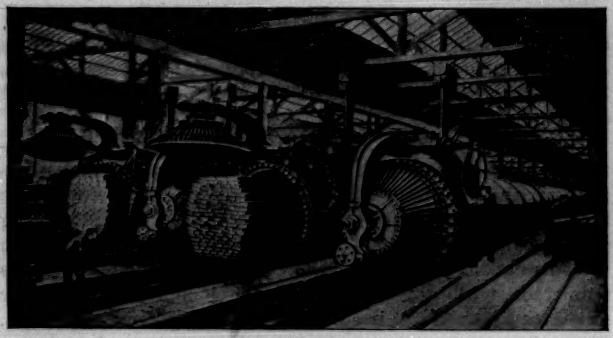


FIG. 1.—Old type of cylinder with external end-gate.

These inventions are the subject of U. S. letters-patent 620,114, February 28, 1899; and 695,678, March 11, 1903, granted to Joseph L. Ferrell, of Philadelphia.

Prior to Mr. Ferrell's inventions the apparatus in general use, and that still used, consists of a large cylinder closed at one end and provided with a movable hinged head at the other, fastened by means of a radial multi-locking system of bolts. This is a bad feature, since it prevents the attainment of high pressures which are desirable for the thorough impregnation of the wood. The cylinders required for practical work are generally so large that it is impossible to

maintain a pressure above 150 pounds. It requires much longer even to partially saturate the wood with such a pressure. (*Fig. 1.*)

In the Ferrell apparatus this objection is admirably avoided by means of an internally-seated gate or valve operated hydraulically. With this apparatus pressures from 400 to 1,500 pounds can be obtained. (*Fig. 2.*)

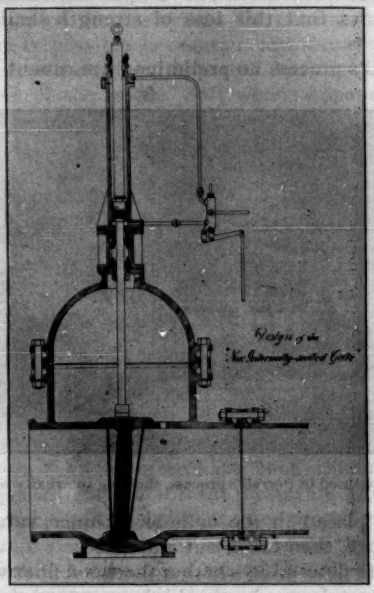


FIG. 2.—Section of internal end-gate.

Again, these cylinders are filled by high-pressure pumps, the shock from which tends to bruise and tear the wood fiber, particularly at the higher pressures. Mr. Ferrell has devised an accumulator which not only maintains a uniform pressure, but serves as a cushion for the pumps. It also serves as an indicator for determining the saturation point;

the pumps cease to act and the pressure is maintained nearly constantly when the wood is thoroughly impregnated. (*Fig. 3.*)

In most processes the treatment consists in depriving the wood of its sap, by first softening with steam, then extracting by drying in a vacuum. This often destroys the wood fiber and usually so reduces its strength that the United States Government, in its specifications for fireproof wood, provides that this loss of strength shall not exceed 30 per cent.

In Ferrell's process no preliminary treatment is required,

FIG. 3.—Cylinder used in Ferrell's process, showing internally seated end-gate.

the wood is placed in the cylinder at once, saturated at a given pressure, then taken out and dried.

In order to determine whether the wood fiber was injured in the slightest degree by the high pressure of the Ferrell process, the committee had prepared a series of large and small test specimens made from representative hard and soft woods for compression and transverse tests and for the determination of the percentage of saturation and the brittlizing effect of the process.

The compression specimens were 4 and 8 inches long, with a section of 1 x 2 inches and 4 x 4 inches respectively,

while the transverse specimens were 36 x 18 inches long and had a section of 4 x 4 inches and 1 x 2 inches respectively. Six specimens of each variety of wood were prepared for each test, one-half of which were treated by the Ferrell process. Mr. Ferrell prepared a similar set, making a total of over 480 specimens.

The tests are not quite finished, but the results will be presented in a final report.

The results of the tests thus far obtained seem to indicate that it is possible to secure a saturation ranging from 25 to 100 per cent. without apparent detriment to the physical qualities of the wood. Soft woods appear to be more readily saturated than hard or resinous woods.

Several visits were made to Mr. Ferrell's experimental plant, and his apparatus was thoroughly examined, as a result of which the committee feels that the inventor has devised and perfected an apparatus that fulfills all the requirements admirably, and that by means of this apparatus it is possible to saturate wood (without injury to its structure) far more quickly and thoroughly than by any other existing machine. That the saturating solution penetrates the very heart of the wood, following the medullary rays from end to end, is another important feature of the Ferrell process.

In his treatment of the chemical phase of the process Mr. Ferrell has been equally successful in the use of sulphate of aluminum. As far as we have been able to determine, this salt possesses most of the desirable qualities of the ideal substance, and we find that wood properly impregnated with it will resist the point of a Bunsen burner for over eighteen hours, a very much longer time than wood treated by other processes.

Under such temperatures the salt is decomposed, leaving an infusible, non-conducting residue to cover and protect the fiber of the wood, in which condition it will not of itself support combustion.

Most of the other salts employed are decomposed and volatilized by such heat—the evolution of a gas or vapor retarding the action of the flame for only a short time.

Sulphate of aluminum preserves the wood, does not promote the growth of fungi, is not hydroscopic, does not produce efflorescence, and does not corrode or rust metallic substances. It has one bad feature, which Mr. Ferrell claims, and appears, to have successfully corrected. The commercial sulphate of aluminum used in the process contains free sulphuric acid, which acts on the iron of the cylinder in conjunction with the tannic acid in the wood, and forms tannite of iron, which blackens the wood. Mr. Ferrell corrects this by neutralizing the acidity with magnesium or ammonium carbonate.

Paint or varnish applied to treated wood remains unaffected for a long period of time.

The committee has also observed a large number of flame tests made (using Bunsen burners) on samples of treated wood of various kinds, and has found that the wood treated by the Ferrell process resists this flame action much longer than wood treated by any other process.

Mr. Ferrell has admirably and greatly perfected the chemical and mechanical features of the art of rendering wood "fire-resistant," and has made it commercially far more available.

In consideration of the fact, therefore, that he has performed a signal and most notable service in his perfection of the process and apparatus for rendering wood "fire-resistant," he is entitled for his investigations to the award of the Elliott Cresson Medal.

Adopted at the stated meeting of the Committee on Science and the Arts, June 10, 1903.

Attest: WM. H. WAHL,
Secretary.

WAGON WITH TWO FIFTH-WHEELS.

A wagon gearing with two fifth-wheels is the invention of Theodore Sandstrom, of Connorsville, Ind., the object being to permit very short turns of the vehicle, and to prevent it from being overturned in case of a runaway or accident. One of these is in the usual place on the front axle, and the other is on the rear axle with a cog connection, so that when the front wheels are turned, the rear ones will be inclined in the opposite direction.—*Scientific American.*

The "Kodak" Developing Machine.

[*Being the Report of the Committee on Science and the Arts, on the invention of Arthur W. McCurdy, of Toronto, Canada.*
Sub-Committee: Lucien Picolet, Chairman; Wm. O. Griggs, J. W. Redpath, Samuel Sartain, Urbane C. Wanner.]

[No. 2266.]

The Franklin Institute, acting through its Committee on Science and the Arts, investigating the invention of Arthur W. McCurdy, of Toronto, Canada, reports as follows:

The awkward tendency of photographic roll-films to curl up in the process of development, the consequent handling required and undue exposure to the dark-room light, have led the manufacturers of this product, the Eastman Kodak Company, of Rochester, N. Y., to place on the market a device with which development can be carried on without the aid of a dark-room and without any handling of the film whatever until it is developed and fixed.

The apparatus is adapted to treat what is known as "daylight film," that is, film covered in the back, its full length, with a strip of black paper before reeling to enable it to be inverted in the camera and removed from it in daylight without injury.

The most obvious method of reducing the amount of handling required to develop each separate picture is to develop the entire film at one operation—a practice of no very recent date among professional operators. A simple apparatus for doing this would consist of a cylindrical roller placed at the bottom of the developer recipient under which the film, face outward, could be drawn back and forth. Enlarge the roller until its circumference is equal in length to the film to be developed, provide means for attaching it thereto, at the same time keeping it tightly drawn against the surface, add a crank for rotating the cylinder and a light-tight cover, and we have the kodak developing machine in its most elementary form.

A cylinder large enough to hold a film of the usual length would be inconveniently large, and in the perfected machines

it is replaced by a flexible strip of celluloid somewhat larger than the film with a strip of corrugated rubber along the full length of each edge. When this is rolled up it forms a spiral with a space between the adjacent coils equal to the thickness of the rubber edging. If the film is rolled along with it, face outward, it occupies the same relative position with respect to the spiral surface as it did in the previous case with respect to the cylinder. This may be mounted on a mandrel and submerged in the developer which finds its way through the corrugated edging between the convolutions of the spiral to the film surface. The complete apparatus is shown in *Fig. 1*, and is manufactured under letters-patent No. 647900, granted to Arthur W. McCurdy, April 17, 1900.

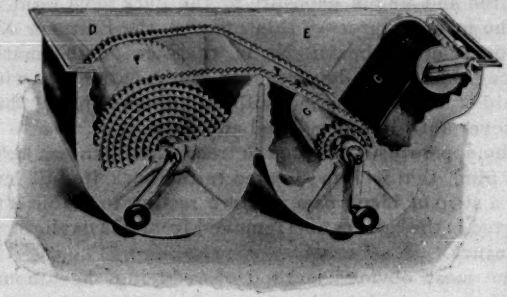


FIG. 1.—Kodak developing machine.

It consists of an oblong metallic, fluid-tight box, divided into two compartments, *D* and *E*, through which pass mandrels *A* and *B*. Compartment *D* merely carries the celluloid strip or "apron" before use, which is transferred to compartment *E* along with the film during operation. A clamp *H* is provided to carry the film spool *K*.

Placing the spool in the holder *H*, a short length of the paper backing *C* is threaded to the spindle *B*, to which is also attached the end of the apron *F*. Enough developer is poured into *E* to half fill it. The box is then covered and the apron *F* and paper strip *C* carrying the film are completely wound upon *B*. With standard developer and at the

usual temperature of living-rooms these are kept in rotation for about five minutes, when development is complete. The developer is then poured off and without any rinsing the fixing bath is introduced and the rotation is continued until the fixing is complete.

Close contact between *C* and *A* is secured by frictional resistance applied to the spool *K* as *C* unwinds. No provision is made for holding the loose end of *C* in contact with the apron *G*, dependence being placed on the adhesive properties of the wet paper, which, being considerably larger than the film, preserves the tension on that part of the paper carrying the film in much the same manner as a comparatively slight tension on the "slack side" of a belt running over a pulley with a large arc of contact will produce a much greater tension on the tight side.

It may be questioned whether treating exposures made under widely varying conditions in the same developer for the same time would not result in many failures. The manufacturers claim that by using the developer they recommend, pyrogallic acid, great latitude in exposure is allowable.

Three six-exposure films, exposed by the Kodak *C*, were developed according to their printed directions. The subjects are outdoor views taken, probably, under one condition of lighting. The excellence of the resulting negatives, submitted herewith, demonstrates without doubt the capabilities of the device for normal exposure.

To further test the machine with varying exposures, three indoor exposures of the same subject were made of five, ten and twenty seconds on a film containing "snapshot" outdoor exposures. The results were perfectly satisfactory and leave little doubt that great latitude in exposure is allowable.

For the excellent performance and certainty of action of the machine and the ingenuity shown in devising the simple and efficient means leading thereto, the Institute recommends the award of the John Scott Premium and Medal to the inventor, Arthur J. McCurdy.

Adopted at the stated meeting of the Committee on Science and the Arts, March 4, 1903.

Attest: WM. H. WAHL, *Secretary*.

Sprague's Multiple-Unit System of Electric Traction.

[*Being the Report of the Committee on Science and the Arts on the inventions of Frank J. Sprague.*
Sub-Committee: W. C. L. Eglin, Chairman; Arthur Falkenau, D. A. Partridge, Clayton W. Pike.]

[No. 2250.]

The Franklin Institute, acting through its Committee on Science and the Arts, investigating the "Multiple-Unit System of Electric Traction," invented by Frank J. Sprague, of New York, reports as follows:

The object of this invention is to permit railroad managers to operate trains made up of any number of units with equal facility, and to enable the train to be rapidly accelerated and maintain the maximum tractive effort on the wheels. This is accomplished by making each unit a motor car and attaching a controlling cable to all controllers, so as to enable the various units to be combined in a train, and operated by a single controller at each end of the train.

The system of control is covered by United States patents:

660065—October 16, 1900.

660066—October 16, 1900.

696880—April 1, 1902.

A brief description of the Sprague system is as follows:

In the hood of each car is a controller for the motors enclosed behind a trap-door which can be lowered for ready inspection. The controller is of the multiple-series type, is driven by a small pilot motor, and provision is made for at will or automatically producing a step by step, or interrupted, or periodic forward movement of the controller, and a continuous or interrupted return movement of it to the off-position through various automatics connected with the pilot motor and the initial control circuits.

In addition to the current-varying controller, there is a main reverser, likewise operated by the same agencies as

the pilot motor, for determining the direction of the current delivered to the motors, and for instantly opening the circuit of the motors in case of emergency.

Inside of each cap is a small master controller or operator's switch mounted on a standard, and fastened to the wood-work of the cab. Through this master controller the pilot apparatus of the current-varying controller and reversers are governed. It is provided with a movable handle, operating a spring-retracted spindle, which, through various degrees of movement, makes contact with the reverser circuit and with three determinate positions, coast, series and multiple. Momentary contacts on these various points give a desired intermediate position of the main controller, which has a stepped movement. In order to maintain the controller at any point, or to keep the governing circuits or train lines energized, the handle of the master controller must be held in position. If the handle is released, whether from accident or design, the spindle instantly returns to coast position, and the controller automatically returns to the off position and cuts off the current, or, if the master controller is allowed to go to the center position, the reverser is instantly opened, and the controller then comes to open circuit also automatically.

The arrangements of circuits is such that by the use of a relay and throttle and the proper interconnection between the controlling circuits the operator is at liberty to do about as he pleases with the master controller, and can rely upon the main controller operating satisfactorily.

For example: He can go to the series or to the multiple position, or, from the last, reverse movement instantly, and the controller instead of responding instantly operates progressively, the pilot being limited in its movements by increment of the main current to or above any definite amount.

The throttle is set just short of the skidding point of the wheels on a normal track, allowing 15 per cent. adhesion, and absolutely limits the current input to that which is required by the determined rate of acceleration. Any rate less than this can also be effected by proper handling of the

motor controller, so that any movements, no matter how refined, are perfectly possible.

This throttle is in the circuit of one motor only, so that it is equally effective, whether in the series or multiple position.

Although there is a master controller on each platform, their construction is such that interference with them is difficult, and has never been known to occur. Of course, they could be made removable.

So far the system described is that of a secondary electric control of a single controller, but by paralleling the relay and other circuits it is evident that the two or more equipments on a single car can be operated, and also that if these equipments are on different cars they can likewise be operated provided means exist for properly connecting the prime controlling circuits, and insuring practical synchronism of the different controls and equal work on the different motors. Where the equipments, however, are on different cars, it then becomes necessary to have a "train line" and couplers, so that a governing circuit, which can be energized at various points, is made up of a train line individual to each car and couplers of some kind between them.

When trains are made up, the train lines are connected by a reversible jumper having corresponding wires, and the system is so disposed and connected that, no matter from which corner the connections are made, or how the cars are reversed or altered in sequence, the circuits are automatically established, so that like track movement is always assured, with like hand movement of the master controllers.

The section of train line in each car is not a part of the normal controlling circuit individual to the control equipment, but is connected with it with switches, which enables a severance of the two systems; that is, the local car system and the train line, so that, no matter how trains may be made up, it is always possible to disconnect the controlling mechanism of any train for any purpose whatever.

The practical result of the system is that every aggregation of cars, whether one or more, has identically the same characteristics in the matter of load, capacity, motor, equip-

ment, rate of acceleration, etc., as are possible with a single car, and every combination is made without the slightest thought being given to pairing of electrical circuits.

Each car is equipped with an automatic air brake system, supplied by Christensen air compressors, with a reserve tank and an equalizing pipe running from car to car, the compressors being started and stopped automatically through an air-governed switch by fall and rise of air pressure.

On each platform, alongside of the master controller, is a small engineer's valve, so that from any selected cab the air-brakes can be operated with equal facility.

A balance wire runs throughout the train, and is included in the same coupling as connects up the electrical train line, so that when an air-governor on any car closes circuit, all compressors start and continue in operation until the last governor throws out. This is to effect equal work on the various compressors, and to maintain absolute certainty of air supply at all times.

If the train should part, three systems of automatics come into play. The reversers go to open circuits, the controllers to the off position, and the air-brakes also automatically operate.

If the main circuit fails, all reversers open instantly, and the controllers must come to the off position, which they will do automatically as soon as current is restored, before current can again be put in the main motors.

So, too, if there is an instant reversal of the master controller. The reversers first open circuit, the controller returns to the off or any determined position, then start again, and are instantly arrested on the first contact. Provision is made so that it is impossible to run backward at more than one-half speed from any platform when operating from that platform.

It would appear that there are two meritorious characteristics presented: First, the system or scheme of train operation by combining motor units, which, we believe, was first suggested by Mr. Sprague. Second, a method of successfully accomplishing this result.

The investigating committee has carefully examined the

various diagrams and printed matter presented, and find that all of the requirements have been carefully and ingeniously worked out. The committee also has communicated with some of the railroad companies using this system, and in their replies they have endorsed its practical success.

In view of the many obstacles which the inventor had to overcome, and because of the very important advance which his inventions have made in the operation of railroads by means of electricity, not only reducing the cost, but also facilitating the transportation of passengers, the award of the Elliott Cresson Medal is made to the inventor, Mr. Frank J. Sprague.

Adopted at the stated meeting of the Committee on Science and the Arts, April 1, 1903.

Attest: WM. H. WAHL,
Secretary.

Notes and Comments.

EXPERIMENTS ON THE RATIO OF GRATE SURFACE TO HEATING SURFACE OF STEAM BOILERS.

At the works of the Yarrow shipbuilding firm of London, interesting experiments have been carried out concerning the ratio of the grate area to the heating surface of boilers. This is an important consideration, as upon this proportion depends to a very appreciable extent the efficiency of the boiler, especially if it is of the water-tube type. For the purposes of these tests a water-tube boiler equal to 1,200 indicated horse-power was employed. This boiler had 1,008 tubes, each 1¼ inches outside diameter, with an average length of 6 feet 9¼ inches. The test was conducted with a boiler having 53 square feet of grate, and with 3,217 square feet of heating surface, giving a ratio of 1 to 60·7. In the second test the grate was reduced to 40 square feet, with a slight change in the heating surface, giving a ratio of 1 to 78·2. The results showed that there was a much higher evaporative efficiency with the smaller grate. Each pound of fuel consumed gave with the small grate 10·57 pounds of steam, while in the other case it only gave 9·96 pounds. But it was also decided that, irrespective of this, the same boiler should give an equal volume of steam, and thus the quantity of coal consumed per square foot of grate had to be increased. For instance, with the larger grate the rate was 29·7 pounds of fuel, and with a less area 39·31 pounds. To burn the greater quantity more draught was required, 0·75 inch as compared with 0·36 inch. These results are highly valuable, for the greater efficiency of the small grate would reduce the fuel consumption on a vessel to a very appreciable extent. The explanation of this greater efficiency is that the gases of the fuel

are consumed more quickly, and are not so likely to come into contact with the cold surfaces of the tubes in an unburnt state.—*Scientific American.*

PRODUCTION OF MICA IN 1902.

With the passing of the stove and the coming of the register and radiator, one of the chief uses of mica has declined. On the other hand, there is an increased demand for smaller pieces of mica that were formerly thrown on the scrap pile. The variations in use, production and importation of this familiar mineral are set forth in a report on the "Production of Mica in 1902," by Dr. Joseph A. Holmes, an extract from the annual volume of "Mineral Resources," published by the United States Geological Survey.

The total quantity of mica produced in the United States during the year 1902, as reported to the Survey, was as follows: Plate mica, 373,266 pounds, valued at $83,843; scrap mica, 1,028 short tons, valued at $13,081; and mica rough as mined, or unmanufactured, 372 short tons, valued at $21,925, making a total value of $118,849.

The increase in the production of plate mica during the last three years is due to the increasing quantity of small-sized mica disks and rectangular sheets that have been cut for electrical purposes. Some of the small, clear pieces obtained in cutting up the large sheets are now split very thin, re-arranged and cemented closely together, forming large sheets called micanite, which are then cut into the shapes and sizes desired. For some purposes these sheets of micanite answer as well as the natural sheets, and have the advantage of being much cheaper. In recent years, scrap mica has been manufactured into a covering for boiler tubes and steam-pipes, to take the place of the more expensive asbestos coverings. Waste mica not available for other purposes is used in the manufacture of wall-papers and lubricants. During 1902, there was, however, a large falling off in the production of scrap mica, which, in 1902, amounted to 1,150 short tons, valued at $14,606, as against 2,171 short tons, valued at $19,719 in 1901.

The tables, which show the great increase in the importation of mica during 1902, are significant. This increase, valued at $131,278, is larger than the total value of the product of mica in the United States during 1902. It illustrates the increasing demand for mica in this country, but also suggests the sad fact that mica can be mined in India and landed in this country at a lower price than it can be mined in some places in the United States. Canada is also a large contributor to our mica supply. It is unfortunate for the industry that many of our mines are owned by small producers who are entirely dependent upon one little mine. When the mica in this begins to give out, or is poor, they have no means to carry on much dead work, and have no other deposit to help fill out this deficiency.

Although mica is widely distributed in the United States, actual mining has been limited, during the last few years, to North Carolina, New Hampshire, South Dakota, New Mexico, Idaho, Virginia and Colorado. Some development work has also been carried on in California, Nevada, Maine, Alabama and Georgia. In several of these States good deposits of mica are known to exist that are not now available on account of their distance from railroads or other means of transportation.

BOUNDARIES OF THE UNITED STATES.

A publication that finds a logical place in the library of both the historian and the geographer is a bulletin (No. 226) entitled "Boundaries of the United States and of the Several States and Territories, with an Outline of the History of all Important Changes of Territory," which has just been published by the United States Geological Survey for gratuitous distribution. The author is Mr. Henry Gannett, who prepared this paper in its first form in 1885, when it was published as Bulletin No. 13. A second edition, much enlarged, constituted Bulletin No. 171, published in 1900. The present work is therefore a third edition, and is its own recommendation.

Besides giving the present boundaries of the country and of the several States and Territories, as defined by treaty, charter or statute, Mr. Gannett presents briefly the history of all important changes of territory and the laws appertaining to those changes. He shows how the boundaries of our country have been affected by the provisional treaty of the United States with Great Britain in 1782, by the treaty with Spain in 1798, by the definitive treaty with Great Britain in 1783, by the treaty of London in 1794, by the treaty of Ghent in 1814, by the treaty with Great Britain in 1842 and by the Webster-Ashburton treaty with Great Britain in 1846.

The additions of territory that have come to the United States and the consequent changes in boundary lines are described. They include the Louisiana purchase, the Florida purchase, the Texas accession, the Mexican cession, the Gadsden purchase, the Alaska purchase and the acquisition of the Hawaiian Islands, Porto Rico, Guam, the Philippine Islands and Tutuila.

An historical review is given of the changes that have occurred in the public domain. A detailed account is also presented of the way in which the present boundary lines of the various States and Territories have been developed. The bulletin, in short, contains in convenient form a great quantity of information that will be useful to the student, teacher, legislator and general reader.

BRONZE FOR HEAVY GUNS.

A pamphlet has been published by the Austrian War Ministry concerning the utilization of bronze instead of steel in the manufacture of heavy guns. Austria is now the only country which employs bronze as the material for its heavy cannon, and it is the intention of the government to retain it. This official pamphlet states that this bronze, forged according to a secret process, is equal to nickel steel. Moreover, the cost of the inner tube is three-fifths less than that of the steel tube. Another advantage is that an injured bronze gun can have a new jacket fitted to it, which is difficult with a steel one. Lieutenant Field-Marshal Uchatius, who in the seventies discovered a special process for forging bronze, also found that good homogeneous bronze could be hammered in a hot or cold state, and therefore can be improved in quality. Lieutenant Field-Marshal Frederick Thiele, the present director of the Vienna Arsenal, also obtained very favorable results in forging this metal, producing a kind of bronze not surpassed by the best cannon steel, through a combination of metals, careful alloying and judicious rolling.—*Engineering and Mining Journal.*

THE RUSTING OF IRON.

W. R. Dunstan publishes a summary of the present results of an unfinished inquiry into the reactions involved in the rusting of iron. While both liquid water and oxygen are necessary for the formation of rust, the presence of carbonic acid is not essential, although it may accelerate the action. The well-known effect of alkalies and alkaline salts in preventing oxidation of iron has been hitherto attributed to the withdrawal of the carbonic acid. It has been found, however, that the phenomenon is not due to this cause, but to the establishment of conditions in which the production of hydrogen peroxide is inhibited. When highly purified iron, containing mere traces of impurity, is left in contact with dry gases (oxygen, carbon dioxide, mixtures of oxygen and carbon dioxide), rusting does not take place. In the presence of the same gases and water vapor, no rusting occurs so long as a constant temperature (34° in the actual experiments) is maintained; but if the temperature is allowed to fluctuate, liquid water condenses on the surface of the iron and rust is produced. It is thus shown that pure iron is not oxidized in presence of gases and water vapor only, but that the presence of liquid water is necessary for rusting to take place. In another series of experiments pieces of iron were left in contact with water saturated with a particular gas and with an atmosphere of the same gas above the solution. When hydrogen, carbon dioxide or nitrogen which had been carefully freed from oxygen was employed, rusting did not occur, but if oxygen or a mixture of oxygen and carbon dioxide was used, oxidation took place. From these results, it is evident that for the formation of rust both oxygen and liquid water are required. In the experiments in which a mixture of oxygen and carbon dioxide was used, the results observed indicated that in this case a secondary action proceeds simultaneously.—*Proc. Chem. Soc.*

Book Notices.

Werkstatt-Betrieb und Organisation, mit besonderem Bezug auf Werkstatt Buchfuehrung, von Dr. phil. Robert Grimshaw. Hanover: Gebr. Jänecke, 1904. (Price, Rm. 20.)

This work, as explained by its title (Shop Management and Organization, with Special Reference to Shop Bookkeeping), gives all the details of shop management, book- and time-keeping in the most prominent American shops, illustrating several hundred forms, slips and cards used in shops and offices to accompany the raw material through all its stages in the different shops until it becomes a completed article ready for use or shipment.

It is fully explained how all this, arranged into a system, complete for each particular purpose, enables manufacturers to obtain their productions with the least expense in the shortest possible time, and with almost absolute security against failure, losses and mistakes, and that the introduction of such systems has enabled American manufacturers, in spite of greater cost of labor and material, to compete successfully with their European rivals, not only in supplying articles cheaper, but more perfect in every way. The introduction

of labor-saving machinery, of piece work and premiums, etc., is shown as forming part of these systems, and is ably treated in this work.

That it has been possible to obtain all this information for publication certainly speaks well for the public spirit of our manufacturers, and the author pertinently remarks that their liberality is in direct proportion to their enterprise, progress and reputation. H.

Ready Reference Tables. Volume I. Conversion factors of every unit or measure in use, including those of length, surface, volume, capacity, weight, weight and length, pressure, weight and volume, weight of water, energy, heat, power, force, inertia, moments, velocity, acceleration, angles, grades, time, electricity, magnetism, electro-chemistry, light, temperature, money, etc., etc., based on the accurate legal standard values of the United States. Conveniently arranged for engineers, physicists, students, merchants, etc. By Carl Hering, M.E., Past President American Institute of Electrical Engineers, etc. First edition. New York: John Wiley & Sons; London: Chapman & Hall. 1904. (12mo, pp. xviii + 196.)

The author in this volume substantially enlarged and elaborated an earlier publication relating to the same subject. He appears to have spared no trouble to make his conversion tables thoroughly reliable. He claims that his figures are not mere compilations from existing books on the subject, but that they have been specially re-calculated for this volume from legal fundamental values specially obtained, where such were obtainable, from the National Bureau of Standards, the Director of the Nautical Almanac, the United States Coast and Geodetic Survey, and, in other cases, from the recommendations of various International Congresses, National Societies and from the best authoritative sources elsewhere accessible.

With this assurance from an author of Mr. Hering's reputation, engineers and others will doubtless feel disposed to accept the results of his work with gratitude. The time- and labor-saving to the professional man, which this work represents, can only be properly appreciated by an inspection of its contents. W.

Éléments de Chimie Inorganique. Par Prof. Dr. W. Ostwald. Traduits de l'Allemand par L. Lazard. Première partie. Metalloides. (8vo de ix + 542 pp., avec 106 figures.) Paris: Gauthier-Villars. 1904. (Price, 15 francs.)

The present French translation of the first part of Ostwald's well-known work on inorganic chemistry has been edited and revised by the translator from the second edition of the German original. It embraces the consideration of the modern concepts of physical chemistry, of which Ostwald is one of the most eminent exponents, and the metalloids. W.

The Practical Photographer. Editors, Rev. F. C. Lambert, M.A., Thos. Harrison Cummings. Boston: Photo Era Publishing Company. Monthly. (Price, 25 cents per number.)

This new photographic periodical represents what may be termed a new departure in serial literature of its class, inasmuch as each number is devoted exclusively to the treatment of a single branch or feature of the art. Thus the first impression (April, 1904) is devoted to "Trimming, Framing and

Mounting;" the second to "Printing on Bromide and Gaslight Papers;" and the third to "Developing and Developers."

The publication is well printed and fully and attractively illustrated. The articles in each issue are from authors of repute.

The field of periodical photographic literature is already over-crowded; but the special and original features of this new candidate for admission to its ranks should command for it a favorable consideration. W.

Jahrbuch der Elektrochemie. Begründet und bis 1901 herausgegeben von Prof. Dr. W. Nernst und Prof. Dr. W. Borchers. Berichte über die Fortschritte des Jahres 1902. Unter Mitwirkung der Herrn Dr. P. Askenasy, Nürnberg, u. A., herausgegeben von Dr. Heinrich Denneel, ix Jahrgang. (8vo, pp. ix + 750.) Halle a. S. Verlag von Wilhelm Knapp. 1904. (Price, M. 24.)

No more convincing evidence of the tremendous strides that have been made within recent years in this branch of applied chemistry can be found than is afforded by an inspection of this imposing volume of 750 pages, in which is set forth with encyclopedic conciseness the noteworthy items of progress for the year 1902. The field appears to have been covered with the same thoroughness that has characterized the previous volumes of the series, and being the only authoritative year-book on the subject, it is simply an indispensable work of reference. W.

De l'Accapanement. La concentration industrielle en France. Par Francis Laur. Ancien deputé de la Siene et de la Loire. Lettre-preface de M. J. Méline, Senator des Vosges, etc. (Tome troisième Deuxième edition.) Société Anonyme des Publicators Scientifique et Industrielle. Paris, 1905.

This volume is devoted to the consideration of questions growing out of the adaptation of French manufacturers to the modern "trust" methods, which have wrought so radical a change in the methods of American manufacturers. W.

Les Applications des Aciers au Nickel avec un appendice sur la theorie des Acier au Nickel. Par Ch. Ed. Guillaume. Paris: Gauthier-Villars. 1904.

This volume gives in concise form the modern views, derived from experiment, of the various kinds of nickel steel and a consideration of the theory of the subject. W.

Committee on Science and the Arts.

(*Abstract of the proceedings of a special meeting, held Tuesday, June 21, 1904.*)

PROF. LEWIS M. HAUPT in the chair.

Present, 19 members.

The meeting proceeded to the consideration of reports, as follows:

(No. 2186.) *Tangential Water Wheel.* Wm. A. Doble, San Francisco, Cal. (A re-investigation.)

ABSTRACT: A report was made on this application at the committee's stated meeting held October 1, 1902, and a brief abstract thereof was pub-

lished in the JOURNAL of the following month (*vide*, Vol. CLIV, p. 397). This was made the subject of a protest from the Pelton Water Wheel Company, of the same place. A reconsideration of the report followed, and the whole subject was reviewed by the sub-committee. An amended report was presented, and after due consideration was adopted at the special meeting above named. Its conclusions are as follows: "Although the Institute recognizes, principally, the original work in the ellipsoid bucket (of the inventor), it also wishes to recognize the improvements in the nozzle, and therefore recommends the award of the John Scott Legacy Premium and Medal to Wm. A. Doble, of San Francisco, Cal., for his improvement in the form of buckets for tangential water wheels, and for his successful adaptation of engineering principles to nozzles for the design of a new form." (*Sub-Committee*, Arthur M. Greene, Jr., chairman, Edwd. T. Child, John E. Codman.)

(No. 2279.) *The Invention of the Electric "Buzz" Fan.* Dr. Schuyler S. Wheeler, Ampere, N. J.

ABSTRACT: Dr. Wheeler's claims that were investigated by the committee were to the effect that he had been the first to devise and perfect a practical and efficient fan motor substantially the same as that in use at the present time.

The sub-committee, after a personal investigation of the evidence submitted by Dr. Wheeler, and an extended examination of the available literature bearing on the subject, solicited and received from a number of experts, presumed to be familiar with the history of this branch of the electric art, an expression of their views as to the accuracy of Dr. Wheeler's claims, and the answers received were so uniformly favorable, in all cases where a positive expression of opinion was given, that the sub-committee felt justified in admitting the applicant's claims, that he was the first to devise an efficient apparatus for this purpose for use on commercial circuits.

The award of the John Scott Legacy Premium and Medal is accordingly made to Dr. S. S. Wheeler for his contribution to the practical development of the electric fan motor. (*Sub-Committee*, Francis Head, chairman, Richard Gilpin.)

(No. 2281.) *Reducing Attenuations in Long-Distance Telegraph and Telephone Lines.* M. I. Pupin, New York.

(Protested by Mr. C. J. Reed. Report referred back for consideration.)

(No. 2294.) *Coal-Loading and Screening Machine.* Henry Jerome Seitz, Philadelphia.

ABSTRACT: The machine is the subject of United States letters-patent No. 681,142, August 20, 1901, granted to H. J. Seitz, and has for its object the loading of coal from piles into wagons, and, incidentally, screening the material.

Without the aid of illustrations, a general idea only can be given of its construction and operation. It is mounted on wheels so that it may be advanced into the pile, or moved from one pile to another. The power is transmitted through chains from the steam engine to the rear wheels, either wheel being operated at will by means of clutches.

The same engine drives the elevator and scraping conveyor. The latter is hinged on the front of the frame, and so arranged that its outer end may be

moved in a vertical plane to conform to the pile of coal. The purpose of the scraping conveyor is to supply coal to the elevator. The coal is discharged into chutes, and is screened during its passage to the wagons. If desired, two wagons may be loaded at the same time.

The machine examined by the committee loaded about one ton per minute and appeared to be an efficient machine. Six (6) men were formerly employed for this purpose, while, with the machine, but two (2) were needed.

The report concludes that while the machine does not embody much that is original, it is nevertheless an efficient combination of parts. A Certificate of Merit is awarded to applicant. (*Sub-Committee*, Chas. Day, chairman; Thos. P. Conard, Kern Dodge.)

(No. 2307.) *Automatic Electric Semaphore Signal.* J. William Lattig, Wyncote, Pa.

ABSTRACT: This invention is the subject of the following letters-patent of the United States granted to applicant, viz., Nos. 496,786–7, May 2, 1893, and 499,125–6, June 6, 1893.

After reference to some correspondence with manufacturers on the subject of prior inventions in this field, to wit, Automatic Electric Disc Signals, Automatic Semaphore Signals operated by means of compressed air electrically controlled, and Electric Semaphore Signals for use in interlocking plants, the report continues:

"What Mr. Lattig actually did was to design a train gearing that, by taking eight or ten seconds, would enable him to work a semaphore by means of an electric motor energized by from ten to twenty cells of potash battery. Mr. Lattig took an electric motor actuated semaphore signal and an electric control and operation—both already old in the art—and combined them.

". . . A few of the Lattig signals have been used on the Lehigh Valley Railroad for a number of years, and the signal itself forms the basis of a number of improved signals now coming into more general use."

The report finds that the applicant was the first to devise a practical automatic electrical semaphore signal, which, though embodying essential features of prior patents (Farrar, Ramsay and Weir), constituted, nevertheless, a more practical and economical device. The award of the John Scott Legacy Premium and Medal is recommended. (*Sub-Committee*, Richard L. Humphrey, chairman; Richard Gilpin, H. S. Balliet.)

(No. 2308.) *Unhairing and Tanning Animal Skins by Electricity.* George D. Burton, Boston, Mass.

(An advisory report.)

(No. 2316.) *Reconstructed Milk.* Charles H. and Pearl T. Campbell, Bayonne, N. J.

ABSTRACT: This invention embraces a method of treating milk for the purpose of preserving it. It comprises two successive operations, the first of which concentrates the solid constituents of the milk in a partially or wholly dried condition, while the second reconverts it into its original form of natural milk.

The several processes involved herein are not susceptible of intelligible description without the aid of drawings.

The committee's conclusions are as follows: "The practical importance of a process of treating milk so that this almost indispensable product may be

effectively preserved in a dried state and eventually restored to a liquid form in a practically normal condition, is so obvious as to need no special elucidation. That this desideratum has been attained in the Campbell process of concentrating and remaking milk is being demonstrated in commercial practice." The award of the John Scott Legacy Premium and Medal is recommended to the inventors. (*Sub-Committee*, Louis E. Levy, chairman; Harry F. Keller, William O. Griggs.)

(No. 2321.) *Alumino-Thermics.* Hans Goldschmidt, Essen, Germany.

This report relates to the inventions of Dr. Hans Goldschmidt, of Essen, in utilizing, by various means, the very high temperatures accompanying the chemical reaction of aluminum with certain metallic oxides, such as oxide of iron. (The report is reserved for publication in full.) The award of the Elliott Cresson Medal is made to the inventor. (*Sub-Committee*, H. F. Keller, chairman; Henry G. Morris, A. E. Outerbridge, Jr., G. H. Clamer, Victor Angerer, James Christie.)

(No. 2326.) *Feed-Water Regulator.* Amos E. Burrows, York, Pa.

ABSTRACT: The automatic steam-pump regulator is applied to a single boiler, and consists of a vertical cylindrical vessel of cast iron, which is placed in the water column of a boiler, and may have the usual gauge-glass and gauge-cocks attached to it. Within this cylindrical vessel is a copper float, with spindles on top and bottom, the upper spindle having a set of levers connected to it, to which is attached a small ball-valve in such a manner that the raising of the float will close the valve.

This valve being at the end of the feed-pump steam-pipe, its closing will stop the pump. The sinking of the water line, in lowering the float, carries the lever system attached to the float to open the valve, thus starting the feed-pump. One of the levers in the system is connected to a small whistle on top of the regulator, so that the sinking of the float to a certain distance admits steam to the whistle, sounding it.

The automatic feed-water regulator is similar in construction, having a cylinder in the water column, with a float. The top spindle of the latter, however, is only connected to the low-water alarm whistle, while the lower spindle works a set of levers, which open or close a valve in the feed-pipe by the lowering or raising of the float.

This regulator is applied to each boiler, where a number of boilers are fed by one pump, so that the feeding of each boiler is regulated by its own water level. When the feed valves to all boilers are shut, the pump is stopped by a diaphragm back-pressure valve attached to the steam pipe of the pump, the increased pressure in feed pipe—due to all feed pipes being shut—acting on the diaphragm so as to close the steam valve. A spiral spring with adjusting screw regulates the pressure at which the valve is to be closed.

The automatic steam pump regulator is covered by United States letters-patent No. 507,211, October 24, 1893, and the feed-water regulator by patent No. 618,981, February 7, 1899.

The report finds that these devices are extensively used in practice, and give entire satisfaction, exhibiting a considerable economy of fuel.

The award of the John Scott Legacy Premium and Medal is recommended to applicant. (*Sub-Committee*, John Haug, chairman; J. M. Emanuel, Chas. E. Ronaldson.

Improved Machinery, Apparatus and Processes.

[This department will contain from month to month descriptions of new machines, apparatus and processes. The data, for which the editor must depend largely on information derived from interested sources, will be carefully edited. The Committee disclaims responsibility.—THE COMMITTEE ON PUBLICATIONS.]

THE RENOLD SILENT CHAIN.

To properly appreciate the advantages possessed by the Renold Silent Chain, which are set forth in what follows, it will be necessary to allude to some of the defects of ordinary chains, and then to point out how these are overcome by the Renold type. The defects of ordinary chains are:

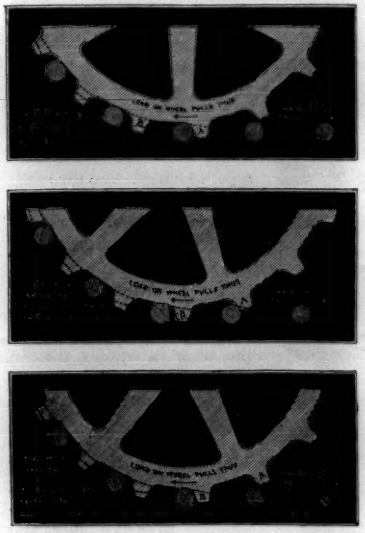


FIG 1.

First, the stretching of the pitch, caused by wear, which occurs to such an extent that the chain becomes useless before the links are worn out.

Second, one tooth only sustains the load, and, passing it on from tooth to tooth, a more or less uneven, noisy and hard-working action is produced. This transfer of load is very clearly illustrated in the accompanying *Fig. 1.*

The Renold Silent Chain was designed with a view, first, of lessening the stretching by increasing the wearing surface of pin and bearing; second, of reducing the noise, by so designing the tooth that the load shall glide gradually from tooth to tooth; third, of reducing the work of the tooth by making the tooth spaces not only just sufficiently large for the chain to bed, but also for the loaded chains to glide, however slightly, on the wheel circumference as one tooth after another goes out of gear. The work becomes thus divided between the tooth and frictional surface contact of the wheel circumference. This gliding action is shown in lower half of *Fig. 2.* It will be noticed that

every tooth in mesh is in direct working contact with the chains. This results in a minimum of wear and a maximum of efficiency.

Fig. 3 illustrates the latest development of the Renold Silent Chain, namely, the bushed type, which was designed and patented by James Mapes Dodge, of Philadelphia. In this chain the wear is transferred from the hole in link to case-hardened bushings, thereby reducing elongation to a minimum; the bushing presents an unbroken surface to the pin, greatly increasing the bearing area, and in addition acts as a retaining wall for lubrication, as a direct result of which the chain can be run at a higher speed than the non-bushed type, which allowed the lubricant to escape and the pins to become dry and eventually burn. In the bushed type there is absolutely no connection between pin and hole of link, consequently the pin is at all times free to rotate and the wear is equally distributed.

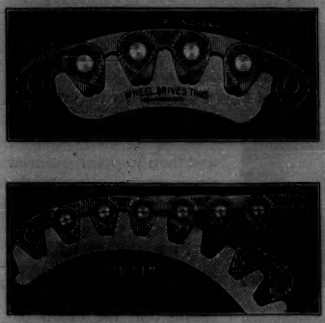


FIG. 2.—The action of the Silent Chain.

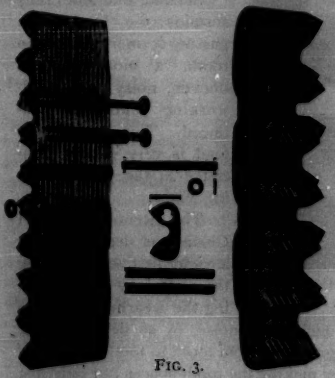


FIG. 3.

Plain Side Links
½", ⅝", ¾"
Pitches

Countersunk Side Links
1", 1¼", 1½", 1¾", 2"
Pitches

Fig. 4 illustrates a 500 horse-power drive from a motor to a gas blower. It will be noticed that there are two strands of chain in operation. As it is practically impossible to make pins and bushings accurate enough to assemble properly in chains over 12 inches wide, the 20-inch width necessary is obtained by using two chains each 10 inches wide.

To distribute the load properly between the two chains and to prevent unequal wear, two wheels with removable hubs, the latter having external lugs which correspond to lugs on the inside of the rim of wheel, are employed, and between

each pair of lugs is inserted a spring of sufficient strength to sustain the pull to be transmitted.

This method of transmitting power is said to be rapidly growing in favor, eliminating, as it does, fixed centers, economizing space, and reducing power loss. The efficiency of this drive by test is claimed to be as high as 98·2 per cent. The Link-Belt Engineering Company, Nicetown, Philadelphia, are the manufacturers.

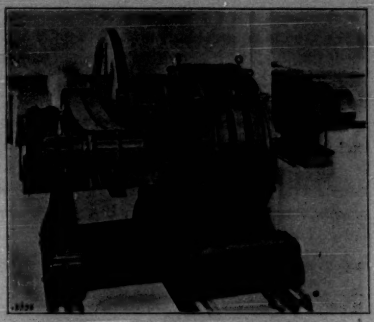


FIG. 4.—500 H. P. Silent Chain Drive operating Gas Blower. Speed, 1,900 feet per minute.

NILES FORTY-TON YARD CRANE.

Illustration is given herewith of the latest type of an approved and economical apparatus for the handling of heavy and bulky freight in a railroad yard. The view shows a portion of the yard of the Buffalo & Allegheny Valley Division of the Pennsylvania Railroad Company, and includes a 40-ton Niles Overhead Electric Traveling Crane, 48 feet span, and a substantial structural steel runway 40 feet long. The crane spans three tracks, and leaves a wide passageway which gives ample approach for teams and trucks on one side of the cars covered by this apparatus.

In addition to the main hook, a quick-running auxiliary hook of 5 tons capacity is provided for the rapid and efficient handling of light loads, which performs by far the greater part of the service of the crane.

The bridge consists of two heavy curved girders, of box section. It is driven longitudinally on the runway by an electric motor located on the front girder, which is geared to the truck wheels on either side, the motion being controlled by a foot brake located in the operator's cage, which acts directly upon the armature shaft of the motor.

A foot bridge is provided the entire length of the span, with customary guard rail.

The bridge trucks are of built-up type, securely fastened with the utmost rigidity to the girders, provided with heavy cast steel, double-flanged truck wheels, with treads accurately finished to uniform diameter.

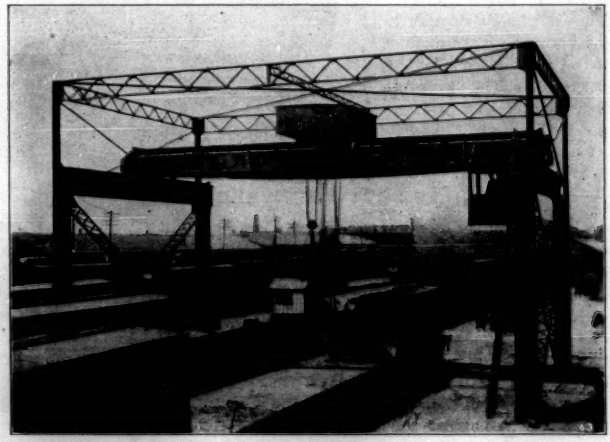
The trolley is the standard type used on overhead cranes, consisting of heavy side frames securely bolted together and kept in perfect alignment by a separator.

All the gearing is cut from the solid and runs encased in oil, which gives the entire mechanism an unusually high mechanical efficiency.

Both hoists are provided with mechanical and electric brakes, also circuit breaker and limit switches to prevent overwinding and consequent damage to the crane or its load.

The trolley, operator's cage and bridge drive motor are of the inclosed type, affording suitable protection from the weather.

The runway, it will be noticed, is of substantial construction. It consists of four built-up columns carrying runways of riveted plate and channel construction, laterally braced by overhead struts and chords of lattice construction.



It will be readily appreciated that an equipment of this character has a much greater capacity than the average pillar or swinging crane, which, where any is in use, is usually installed at railroad freight stations.

If at any time it is desired to cover increased acreage by the hook, the length of runways is readily increased by adding additional spans.

This crane is notable also because of the extra height of lift, which enables the loaded hook to clear the top of box cars or other obstructions while performing the functions of its regular service of loading and unloading.

The complete apparatus was manufactured, installed and erected by the crane department of the Niles-Bement-Pond Company, Meadow and Mifflin Streets, Philadelphia, Pa.